STUDIES OF PLANT LIFE

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A SERIES OF EXERCISES FOR THE STUDY OF PLANTS

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PREFACE.

THIS small volume has been prepared as the result of a real necessity for a more careful study of plants and their life activities. During a number of years of experience as instructors of Botany in the Chicago secondary schools, with desirable classes, good laboratories, and ample equipment, genuine progress ought to be expected in the study of plant life. The work herein indicated represents the results of such experience up to the present time. As to how well it may succeed in its purpose remains for those who use the book to demonstrate, but the hope is expressed that it will be found to meet all the exacting requirements of to-day reasonably well.

Few sciences have undergone such marked change in nomenclature and interpretation as has the subject of Botany. In this series of studies the purpose is to acquaint the student with plants as living things, potent factors for accomplishing certain great and important results. It is not so much what the plant is, as what it does, that incites to investigation, and the details of structure are but used as a sure foundation upon which to gather and work out greater problems of function and relationship. The life relations and the influence of environment are to be prominently studied, also the influence of plants on each other, on animals, the soil, water, and the atmosphere. With this kind of study in view, the "Life Problem" questions have been included. These questions are not meant to be exhaustive. Similar questions should be added by both the instructor and pupil.

Experience has demonstrated that the larger plant-life problems can be interpreted only by such careful preliminary study as is herein indicated and honestly and faithfully accomplished.

The microscope and other tools are simply aids to more thorough investigation of the material, and their manipulation ought to be mastered as early as possible and correct habits formed for their proper care. Note and drawing paper should be close at hand and ready for constant use.

These directions for laboratory study are intended to be sufficiently clear to guide a student to a fairly complete notion of material which is properly presented. For a more satisfactory mastery of plant life this series of exercises should be supplemented by assigned reference reading from good text-books, field study, class and lecture work, and, finally, carefully prepared theses, which include drawings and descriptions, giving the essential details of knowledge which has been obtained.

The course is intended to occupy the laboratory time of a pupil for one year, and may be conveniently divided into two great themes, each of which will require half a year for its full presentation. These are, a history of the race from the lowest to the highest forms, dwelling upon the great principles of plant evolution and relationship, and the history of an individual seed plant in all its stages of growth. The order in which these themes are to be presented is a matter of secondary importance, to be governed largely by local conditions and requirements. Either may with propriety be given the precedence as the instructor shall select.

A section on experiments and demonstrations, showing life phenomena of plants, will, it is hoped, be found a

very useful and helpful feature of the work, and one that by means of numbered references may be constantly accessible to the student. It is not expected that all these experiments and demonstrations are to be performed by the student; the instructor may direct or perform the experiment before the class.

The study of plants in their environment is so full of interest and has such an important bearing upon a full and complete comprehension of the plant as a living potential factor on the earth, that some suggestions regarding field study are incorporated, and a sample outline of a possible existing region given as an aid in the working out of this feature of ecological study.

An artificial key for plant analysis has been added, together with a synopsis of the families represented. This key is not intended as a substitute for those of larger systematic works on Botany, but merely as an aid to enable the student to learn the names of some of our more interesting and common flowers without using another book.

The spelling and botanical nomenclature adopted in this work is that preferred by the best and latest authorities.

To those who have favored us with their friendly criticism we herewith make acknowledgment of our appreciations.

THE AUTHORS.

CHICAGO, June, 1900.

CONTENTS.

PART II.

THE COMPOUND MICROSCOPE.

The compound microscope, as used in the laboratory to study very small objects, consists of two distinct parts, — the mechanical part (stand), and the magnifying part (lenses).

A. The Stand.

1. The **base** is the part which rests on the table.
2. The **column** is the vertical portion which is attached to the base and supports the other parts. Has it a hinge? If so, why?
3. The **stage** is the horizontal shelf which is attached to the column. Observe the opening in the center of the stage.
4. The **rotary disk**, if present, is fastened to the under side of the stage, and has openings of different sizes. How is it turned, and what is its purpose? If not present, what takes the place of it?
5. The **mirror** is situated below the stage. To what is it attached? In how many directions can it be turned? Why? Are its two surfaces alike, and if not, how do they differ? Of what use is the mirror?
6. The **tube** in some instruments is held in the **sleeve**, which, in turn, is connected with the upper part of the column by an **arm**. To raise or lower the

tube, slightly turn it at the same time. Such rapid movement is called the **coarse adjustment.** Some microscopes have a "**rack** and **pinion**" for greater convenience in the coarse adjustment. Which has yours?

7. Usually at the top of the column is a "**milled head**" of a screw, which, by being turned, moves the tube a very short distance. This is called the **fine adjustment.**

B. The Lenses.

1. The **eye-piece,** or **ocular,** consists of lenses mounted in a cylinder of metal. Hold it near the eye and look through it toward the light, and observe the area of light. Are objects easily seen through it? To be of use it is placed in the upper end of the tube, and is usually left in this position.
2. The **objective** consists of lenses mounted in a somewhat conical form of metal. Objectives differ in magnifying power, and are accordingly named "low power" and "high power." Much care should be taken of all lenses, therefore hold them by the metal portions only. In looking through objectives the more pointed end should be near the object. How do objectives differ? To be of use an objective is screwed into the lower end of the tube, or accessory **nose piece.**

C. To use the Microscope.

1. With both sets of lenses in position place the microscope with the stage away from you. Arrange the mirror to obtain a bright circular area of white light (**field** of **vision**) as you look through the

lenses and tube. The mirror should be turned at an angle of about 45° toward the window from which the best light comes. Obtain the best diffused light. Do not get the image of the source of light (*e.g.* the sun) in the mirror, and do not take reflected light (*e.g.* that reflected by a wall).

2. Focus.

Place on the stage the temporary or permanent preparation (the 3 in. × 1 in. glass slide, in the center of which is mounted the small object in some fluid medium, and covered by a thin "cover glass"). If the stage is to be inclined by means of the hinge in the column, the slide should be firmly held by the "clips" situated near the edge of the stage. Slowly lower the tube by the "coarse adjustment" until it is very close to the specimen, then look through the lenses and raise the tube until the object comes into view. Then with the "fine adjustment" slightly raise or lower the tube until the object is distinct; at the same time adjust the slide with the other hand. Use low power (l.p.) and then the high power (h.p.). Why? Sketch the object and compare your sketch with the position, direction, and size of the specimen on the slide. What are your observations? Does a hand lens (simple microscope) have the same effect? Why? Read carefully notes 1 and 2.

SUMMARY.

1. Place the lenses in position.
2. Adjust the preparation on the stage.

3. Obtain good light by using the mirror.
4. Focus by means of the "coarse adjustment and fine adjustment."
5. Adjust the object in the "field of vision."
6. Regulate the amount of light by means of the mirror and rotary disk.

NOTE 1. — Small printed letters, or even whole words, mounted on a glass slide, are desirable in a preliminary study as to the use of a microscope. Get the light and focus several times until you have perfect control of all the microscope parts.

NOTE 2. — Whenever the microscope is used, and the study and desirable drawings are completed, carefully arrange the microscope and all its parts ; also return the preparation where requested by the instructor. Or, if it is a temporary preparation, as is commonly the case in everyday work, very carefully clean the slide and cover glass, and place them in good order where requested by the instructor.

STUDIES OF PLANT LIFE.

PART 1.

GROUP I. THALLOPHYTES. THALLUS PLANTS.

STUDY 1.

PLEUROCOCCUS, NOSTOC OR OSCILLARIA.

A. Vegetative and Reproductive Stages.

1. With l.p. and h.p. study plants which have been properly mounted. What is the size, color, and form of the plant?
2. The exterior covering of the **cell** is the **cell wall**; important contents are the **nucleus** and **cytoplasm**, which together constitute **protoplasm**. The green coloring matter of plants is **chlorophyl**. Which of these are present in the specimen?
3. Does an individual plant consist of one or more cells?
4. Are the cells alike? If not, how do they differ?
5. What evidence is there of growth and reproduction?
6. What is the arrangement and relation of the new plant cells?
7. Make drawings: (*a*) an individual plant (del. $\frac{1}{2}$ in.) and designate all of its parts; (*b*) other plants of smaller or larger size; (*c*) stages of reproduction.

8. What is the general appearance of the plant in its place of growth?
9. Some plant cells are inclosed in a jelly-like substance. Is this present?
10. Make a tabulated comparison of these three forms according to the following scheme: —

Plant Name.	Color.	Size.	Shape of Cell.	Cell Arrangement.	Reproduction.	Other Features.

B. Life Problems.

1. Where are each of these plants found?
2. Why is it found in such places?
3. What is the significance of the green color?
4. What is its food and how does it eat?

Experiments 1, 2, 3, 4, and 8.

5. Why is it so widely distributed?
6. How does reproduction occur? Why?
7. How does growth take place?

STUDY 2.

YEAST PLANTS AND BACTERIA.

A. Vegetative and Reproductive Stages.

1. Study mounted specimen with h.p. What is the size, form, and color of the plant cell?
2. What cell structures are present? The clear spaces in the cytoplasm are **vesicles (vacuoles?)**. Are these present?
3. Are single cell forms found? When associated how are they related?
4. What evidence is there of reproduction?
5. Make drawings: (*a*) a single cell (del. $\frac{1}{2}$ in.) and designate the parts; (*b*) other plants of different sizes; (*c*) stages of reproduction.

B. Life Problems.

1. Where do these plants grow? Why?
2. How can it be shown that they are living things?

Experiments 1, 2, 3, 5, and 8.

3. Are they beneficial or injurious? Why?
4. How are they so well distributed?
5. What is their food and how do they obtain it?
6. What substances do they form as products of their activities?
7. Can these plants grow in strong salt or sugar solutions? Why?

Experiment 9.

8. Why is it desirable to boil drinking water?
9. Why are foods preserved by canning?
10. Why is cold storage a means of food preservation?
11. Explain the use of yeast in bread making.
12. Why must the bread mixture be set where it is warm, but not hot?
13. Name other uses of yeast.
14. How is yeast prepared for use? Can yeast be made? Why?

STUDY 3.

SPIROGYRA OR ZYGNEMA.

A. Vegetative Stage.

1. What is the form of the plant body?
2. What color is it and does the color vary?
3. What do you observe by feeling it?
4. If composed of cells, what is their exact form and arrangement?
5. With l.p. or h.p. study cell structures. If color bodies (**chromatophores**) are present, note their number, structure, and arrangement. Is cytoplasm present in other regions of the cell?
6. To what is the color due?

Experiment 14.

7. The enlargements in the chromatophores are **nodules**. Observe their abundance and distribution.
8. Is the nucleus easily observed? Apply iodine and note the result.
9. Apply to a fresh specimen a 5 per cent salt solution and observe the effect.
10. Does the plant have a jelly-like sheath?

Experiment 14.

11. What difference, if any, do you observe in the end cells? Why?
12. Draw two or more cells and designate all the parts and structures.

B. Reproductive Stage.

1. How is the filament increased in length? (**Vegetative growth.**)
2. Is the filament one or several individual plants?
3. With l.p. and h.p. study adjacent filaments with connecting (**conjugating**) tubes, also any variations in cell contents. The union of two protoplasmic bodies (**gametes**) which are similar is **conjugation**, and the resulting body is a **zygospore.**
4. How does the color of the conjugating filaments differ from that of the vegetative stage?
5. Make a drawing showing, if possible, the different stages of this process and designate all parts.

C. Life Problems.

1. Where does the plant grow?
2. Is it free and floating or attached?
3. What is its food and how is it obtained?
4. Can it grow in salt water? Why?
5. Does it need light? Why?

Experiment 13.

6. What is the purpose of the nodule?
7. Of what advantage is the filamentous form?

STUDY 4.

A MOLD. *Mucor.*

A. Vegetative and Reproductive Stages.

1. With m. observe the filaments (**hyphæ**) which together constitute the **mycelium**. If possible study the mold in an undisturbed position, *e.g.* on bread.
2. The visible mycelium consists of **aerial hyphæ**.
3. What is the form and color of the filaments?
4. Is a filament composed of one or more cells? Is it branched?
5. At the distal ends of some erect hyphæ note enlargements (**sporangia**). What is their origin, form, and color?
6. If possible, find the stages of development of sporangia.
7. With l.p. study the contents (**spores**) of a **sporangium**. What is their form? Why so abundant?
8. Are they formed by cell union or cell division?
9. Draw a few **vegetative and reproductive hyphæ** of the mold and designate all parts.
10. In the substratum hyphæ, search for large, dark bodies (zygospores) between the filaments. What is their origin?
11. Try to find the stages of this process, and if found make a drawing.
12. Compare the zygospore of the mold with that of Spirogyra, as to the position, form, and method of formation.

B. Life Problems.

1. Where are the molds found?
2. Explain the origin of the mold plant on foods.
3. What is its food and how does it take it?

Experiments 5, 10, and 8.

4. Why does mold grow on bread and on fruit?
5. What conditions are necessary for its growth?
6. Why does it not have chlorophyl?
7. Why is the mold always on the surface portions of fruits preserved in liquids?
8. Why is it that mold will not grow on clean, moist sand or in pure water?
9. What is the purpose of the sub-stratum hyphæ?
10. Of what advantage is the horizontal position of most of the aerial hyphæ?

STUDY 5.

VAUCHERIA. *Greenfelt.*

A. Vegetative Stage.

1. Under what conditions does this plant grow?
2. What is its general appearance?
3. How could you distinguish this plant from Spirogyra?
4. With l.p. study mounted specimen. What is the form of the plant?
5. Is it composed of cells and does it branch?
6. What is its color and how are the chromatophores arranged?
7. With h.p. study carefully. What cell structures do you observe?
8. Round or oval bodies from which filaments arise are **germinating spores**. If found, study carefully and sketch. What is their origin?
9. Colorless root-like structures are **rhizoids**. Do you find them and, if so, how do you explain their color and function?
10. Apply iodine and note results. What explanation can you give for results?
11. Make a sketch of a filament showing branching, and designate all parts.

B. Reproductive Stage.

1. How many kinds of branches are there?
2. What is their relation to the main filament?
3. How do the distal ends of the branches compare?

4. The elongated, more or less curved branches are **spermaries** and the somewhat spherical ones are **ovaries.** How are they related to each other?
5. Are transverse partitions (**septa**) to be found? Why?
6. Is there an opening in either the spermary or ovary? If so, where and why?
7. At the distal ends of some filaments are enlargements which produce one or more motile bodies (**zoospores**). Are they to be found and what do they become?
8. Make drawings showing reproductive stages, and designate all parts.

C. Life Problems.

1. Of what advantage is its branching?
2. How can it grow on the land as well as in the water?
3. What is the purpose of the rhizoids?
4. How does this plant obtain its food?
5. What is the origin and function of the zoospore?

STUDY 6.

A WATER MOLD. *Saprolegnia.*

A. Vegetative Stage.

1. With forceps remove a few filaments from the source of the material and with l.p. and h.p. study the color, form, and structure.
2. With what previously studied plant does it best compare?
3. Are any of the visible hyphæ horizontal? If not, why?
4. Apply a 5 per cent salt solution, observe the results and explain.

B. Reproductive Stage.

1. How do the distal ends of the various hyphæ compare?
2. The more or less club-shaped distal enlargements (sporangia) produce numerous zoospores.
3. Where are septa present? Why?
4. Make drawings and designate the parts.

C. Life Problems.

1. An organism which obtains nutriment from another living organism (**host**) is a **parasite**. A plant which obtains nutriment from dead organic matter is a **saprophyte**. What is the habit of this plant during its life history?

2. How and why is the water mold so widely distributed?
3. Of what economic importance is it?
4. Why is the zoospore method of propagation usually sufficient?

STUDY 7.

ROCKWEED. *Fucus.* A BROWN ALGA.

This plant grows on rocks at the seashore along the tide line. Its attachments or holdfasts (rhizoids) are not usually present in the material used.

A. Vegetative and Reproductive Stages.

1. The flattened plant body (**thallus**) consists of a midrib and the lateral expansions (**wings**).
2. How does the branching occur?
3. The enlargements are the "**air bladders.**" Where are they situated?
4. Study an opened air bladder. What are its contents?
5. The small reproductive structures, mere specks, on the distal regions are the **conceptacles**, in which are borne the gamete-bearing bodies. Are the conceptacles few or many?
6. Where are they most abundant and prominent?
7. With m. observe their openings and structure.
8. Make a drawing designating all parts and regions.

B. Life Problems.

1. Of what advantage is it in being a flattened thallus?
2. Of what importance are the air bladders?
3. What is the food of this plant?
4. How can it endure drying conditions during low tide?

STUDY 8.

A LICHEN.

A. Vegetative and Reproductive Stages.

1. Upon what does it grow?
2. How is the thallus attached?
3. What is the form and color of the thallus?
4. Observe the **fruiting cup** structures. What is their size and distribution?
5. Draw and designate parts of the thallus.
6. Remove a small piece from a wet thallus and tear with needles, and with l.p. and h.p. observe the different parts. How do they vary in form and color?
7. With what former studies do the structural elements compare?
8. Make a drawing showing the structure.
9. Study a similar preparation of a portion of a fruiting cup and observe the erect hyphæ which bear sporangia. How many spores are there in each sporangium?
10. Do all the hyphæ bear sporangia? If not, of what advantage are the sterile hyphæ?
11. Sketch a portion of a fruiting cup designating all parts.

B. Life Problems.

1. Why is it a thallus?
2. Why is it brighter in color when wet?

3. What is its food and how does it get it?
4. How does it affect rocks and soil?
5. What benefit is the mutualism between the alga and fungus?
6. Lichens are often found growing on trees. Do they damage the tree? Why or why not?
7. Are lichens ever useful to man? If so, how?

STUDY 9.

A MUSHROOM OR "TOADSTOOL."

A. Reproductive Stage.

1. The part more or less elongated is the **stalk** or "stem." What evidence is there which is the proximal end?
2. The expanded distal region is the **pileus**, which bears on its under surface **gills, pores,** or **spines.** Which does your specimens have?
3. If there is a marginal attachment of the pileus to the stalk, it is the **veil.** If present, what is its origin and purpose?
4. If there is a remnant of the veil attached to the stalk, it is the **ring.** Is it present?
5. In a longitudinal section of the plant, with m. observe the structure of the stalk and pileus. Of what do they consist?
6. With l.p. and h.p. study the spores. From what region of the pileus do they originate?
7. If the pileus has gills, where are they the most numerous?
8. Make drawings: (*a*) under surface of pileus; (*b*) a longitudinal section of the stalk and pileus; (*c*) spores; (*d*) a lateral view of the entire mushroom designating all parts.

B. Life Problems.

1. Where do these plants grow?
2. Under what conditions do they thrive best?

3. Are they beneficial or injurious? How?
4. Why do they expose to the air their spore-bearing portions?
5. Is the plant useful as a carbo-hydrate or a nitrogenous food?
6. What is the mutual relationship of these plants and insects?
7. Are the spores few or many? Place on a glass plate a pileus with its spore-bearing surface downward, and cover. Examine after a time and observe the result. How do you explain it?

STUDY 10.

A STONEWORT. *Chara.*

A. Vegetative Stage.

1. With m. observe that the primary or main axis of the plant body consists of joints (**nodes**) and of segments (**internodes**). Are all the internodes of equal length? Why?
2. The circle (**whorl**) of thread-like structures on the main axis are **dwarf branches.** Where are they attached and of what do they consist?
3. Observe the origin of a secondary axis (**branch**) with reference to the dwarf branches. Does it arise from the distal or proximal angle?
4. Find an **apical bud** at the distal end of a primary or secondary axis. How do its parts compare with the regions already studied? Make a sketch of an apical bud.
5. With scissors make a transverse section of a large internode and study with m. the arrangement of the outer (**cortical**) cells and the inner (**internodal**) cell.
6. Make a drawing of an internode section.
7. Are hair-like filaments (rhizoids) attached to the proximal regions? If so, where? Sketch rhizoids.
8. Observe the extent and direction of the cortical cells. Why are they so arranged?

9. Do the internodal cells unite at the nodes or are there **nodal** cells.
10. Of how many cells do the elongated **branchlets** of the dwarf branches consist?
11. Make a careful drawing of the plant, showing all the parts and observations already made.

B. Reproductive Stage.

1. With m. or l.p. observe the form and color of the fruiting structures, a spherical one (spermary), and a somewhat flask-shaped organ (ovary). Where are they situated?
2. Observe the relative position of the spermary and ovary. What significance may this arrangement have?
3. Study the spermary with l.p. and observe the large cells (**shields**) that make up its wall. How are they arranged? Sketch.
4. Crush a spermary and study its contents. Observe the tangled threads (**spermatic filaments**) sometimes with small lash-like cells within (**male gametes**). Sketch filaments.
5. Study the ovary and observe the details of structure.
6. The inclosed large cell is an **egg** (**female gamete**). The protective cells which cover it are cortical cells. How are they arranged and how do they terminate? Sketch and designate all parts.

C. Life Problems.

1. Where does this plant grow?
2. Is it free or attached?
3. Is the plant body a flattened thallus?

4. How and why does it grow erect?
5. Is it smooth or rough? Why?
6. What is the source and purpose of its odor?
7. How does it multiply so rapidly?
8. Is it beneficial or injurious in small lakes? Why?
9. Of what advantage are the rhizoids?

SUMMARY.

COMPARISON OF ALGÆ AND FUNGI.

In general an **alga** is a Thallophyte having chlorophyl, while a **fungus** is a plant of the same group without it.

A.

1. Prepare a tabulated comparison of the plants thus far studied, using the following guide: —

Name.	Habitat.	Color.	Structure.	Reproduction.	Life Habit.	Food.	Economic Importance.	Characteristic Parts. Drawings.

B. General Life Problems.

1. How and why do water algæ assume a filamentous form?
2. Spore production is of what advantage to a plant?
3. Why do some plants have asexual as well as sexual spores?
4. Why do many algæ placed in a mass in a laboratory jar usually die?

5. Is respiration a vital process of these lower forms? If so, how is it performed?

Experiment 12.

6. How is the "balance of life" in an aquarium or small pond maintained?
7. Are algæ and fungi important food plants for animal forms? If so, what?

GROUP II. BRYOPHYTES. MOSS PLANTS.

STUDY 11.

A LIVERWORT. *Marchantia.*

A. The Vegetative Portion.

1. From the general appearance of this plant can it be determined where and under what conditions it grows?
2. The plant body is a thallus and consists of a central median line structure (midrib) with a lateral expansion (wing) on each side.
3. Note the number of branches of the main axis and the plane of branching.
4. Study the rhizoids. On which surface are they? To what are they attached? How do they differ (l.p.)? Do they branch? Of how many cells are they composed? What is their purpose? Sketch.
5. Study carefully with m. the upper surface to find numerous breathing pores (stomates), each of which is in the center of a small stomate area. What is the form of the stomate areas? Sketch four or more adjacent typical ones, showing their stomates. Why does the plant need to breathe? Are there any stomates on the under surface? Why?

B. The Reproductive Portion.

1. The little cups (**cupules**) may be observed to contain small, flat, green structures (**brood buds** or **gemmæ**). What is the location of the cupules. Are their edges complete? If not, where are they incomplete? Sketch one or more cupules.
2. To what are the gemmæ attached (m.)? Are they few or numerous?
3. With l.p. find two lateral indentations (**vegetative notches**), also the place of attachment. Study the form and structure of a gemma. What is its color and why? What food storage has it? (Make tests.) Sketch a gemma.
4. Note the origin of erect stalks (pedicels) the distal expanded portions of which (receptacles) bear the **gamete bodies.**
5. The receptacle having a scalloped margin bears the **spermaries** on its distal surface, and the receptacle having strap-shaped projections about its margin bears on its proximal surface inverted flask-shaped bodies called the **archegonia** (ovaries).
6. An archegonium consists of a **stalk, body,** and **neck.** If possible, see and sketch.
7. How do the thalli, which bear the fruiting structures and the vegetative ones, compare?
8. Note carefully any other structures on the proximal and distal surfaces of the receptacles.
9. In some specimens the **oospore** (the fertilized gamete of an archegonium) may have grown, and in its development produced yellowish bodies (**spores**) and spiral structures (**elaters**). If so, use l.p. and study them. Sketch spores and elaters.

10. Make careful drawings of the entire plant bodies which produce the sperms (**male gametes**) and the eggs (**female gametes**) and designate all the parts.

C. Life Problems.

1. Is there any advantage in the horizontal position of the plant body?
2. How can it successfully take possession of certain considerable areas of soil?
3. What are its methods of multiplication?
4. Why are shade and moisture so necessary to growth?
5. Where is this plant commonly found in cities? Why? How did the plant get started in such places?

STUDY 12.

A MOSS PLANT.

A. Vegetative and Reproductive Stages.

1. Where are these plants found?
2. With m. study the parts of a single plant, to find its rhizoids, stem, and leaves. How do they differ in size, form, and color?
3. Are the plants free or united with each other? What evidence is there for your observation?
4. The erect stalk (**seta**) at the summit of a leafy shoot bears a spore case (**capsule**) at its distal end. Is the seta firmly or loosely attached? Why?
5. Is there a little cap (**calyptra**) on the distal end of the capsule? What is its origin?
6. Draw (del. 3 in.) a single specimen and designate known parts.
7. With l.p. study each part; draw rhizoids and leaves and describe.
8. Remove the calyptra and observe with m. a little lid (**operculum**). What is its use?
9. Draw the structures studied in 4, 5, and 8.
10. Split a capsule lengthwise, and with m. study the position and attachment of the inclosed **sporangium**, and find its contents, the **spores**.
11. Draw and describe.

B. Life Problems.

1. What advantage is there in so many growing together?

2. Why is the plant body erect?
3. Is each plant body simple or compound? Why?
4. Has it stomates? If so, where and why?
5. Explain the advantage and stages of "**alternation of generations.**" Are the sporophyte and gametophyte phases separate? Why?
6. Are mosses of economic importance? If so, how?
7. What is their food?
8. Are they independents or dependents (parasites or saprophytes)?
9. How does the addition of water affect a quantity of moss after excessive drying?
10. How do mosses endure excessive drought?
11. Why are moss plants so successful in cold climates?
12. How are the spores distributed and what do they become in the life history of the plant?

GROUP III. PTERIDOPHYTES. FERN PLANTS.

STUDY 13.

A FERN PLANT.

A. The Sporophyte.

(a) *The Vegetative Portion.*

1. Study the underground stem (**rhizome**). What is its form, color, size, and direction of growth?
2. Is there a ridge (**lateral line**) extending along each side?
3. Are nodes and internodes apparent?
4. Study the roots as to their origin and form.
5. Observe the leaves (**fronds**) as to their origin and form.
6. Search for buds and modified leaves. Where are they found? Why?
7. The frond consists of a leaf stalk (**stipe**) and the blade (**lamina**), which is usually subdivided into primary lobes, which are often again subdivided into secondary lobes.
8. With m. study the vein distribution (**venation**). Sketch a portion to show venation.
9. What evidence is there of former leaf attachments?
10. Make one or more drawings showing the results of your study from 1 to 9 inclusive.
11. Study with m. and l.p. a cross-section of the rhizome, noting the general outline and appearance.

Identify **epidermis** (protective tissue), **parenchyma** (softer storage tissue), **vascular bundles** (conductive and supporting tissue), and **sclerenchyma** (storage and supporting tissue). Study the structure of the epidermis, also the form and distribution of the various other tissues.

12. Draw and name the parts.
13. Study with l.p. and h.p. the epidermis from the dorsal (lower) surface of the lamina, and observe the form and structure of the cells, also the number, form, and arrangement of the stomates and of their guard cells.
14. Draw and designate parts.

(b) *The Reproductive Portion.*

1. Find clusters of fruiting structures (**sori**). On which surface of the lobes are they? How are they distributed?
2. If a protective structure (**indusium**) is present, what is its origin and form?
3. With m. study a single fruit cluster (**sorus**). Find the minute oval bodies (sporangia) and note their arrangement and attachment.
4. With l.p. and h.p. study a sporangium and find its short stalk (pedicel).
5. In an unbroken sporangium study the form and arrangement of the cells. The outer row of darker cells is the **annulus**. Find a sporangium in which the wall is broken. Where, with reference to the annulus, did the wall break? Why?
6. What is the form of the spores? Why so abundant? How are they distributed?

7. Make drawings showing (*a*) the distribution of the sori, (*b*) a sporangium with its pedicel showing details of structure, and (*c*) the spores.

B. The Gametophyte.

1. Study the form and structure of a **prothallium (gametophyte)** (the plant body grown from the fern spore). Are rhizoids present? If so, where? Possibly small spherical antheridia (spermaries) may be found with l.p. among the rhizoids, also rather elongated archegonia (ovaries) nearer the notch (**sinus**).
2. If possible, show all these structures in a careful drawing of the **gametophyte.**

C. Life Problems.

1. Where are the root, stem, and leaf portions? Why?
2. Does it live more than one year? Why?
3. How is it distributed?
4. Under what conditions do ferns grow best?
5. Have ferns been more successful in former times than at present? Why?
6. Is it of any advantage for the fern to have its gametophyte separate from the sporophyte? Why?
7. In spite of so large a production of spores why are ferns not more numerous?

STUDY 14.

AN EQUISETUM, *E. Arvense ; Common Horsetail.*

A. The Vegetative Portion. (*An erect branching form.*)

1. Identify nodes and internodes of the main axis and its branches.
2. Are there leaves? If so, what is their form and arrangement?
3. Are all of the internodes of the same length? If not, why? Are the internodes smooth or rough (m.)? Why?
4. Study longitudinal and transverse sections to discover whether the stem is solid or hollow and where.
5. How do the internodes join each other?
6. Are the walls solid or hollow?
7. Make drawings: (*a*) two or more internodes designating all structures; (*b*) a longitudinal section through a node showing the leaf attachments and the union of internodes; (*c*) a transverse section of an internode designating its parts.
8. What is the form and origin of the roots? (Draw.)

B. The Reproductive Portion. (*Sporophyte.*) (Specimen without branches.)

1. How does it differ in color and structure from the vegetative portion?
2. The distal spindle-shaped **fruiting spike** (**strobilus**) consists of spore-bearing "modified leaf structures,"

sporophyls. Do they have stalks or are they sessile?

3. Of how many sides does the distal flattened portion of a typical sporophyl consist? Why?
4. Observe the form and position of the sporangia. What do they contain?
5. With h.p. study the spores. What is their form, color, and structure? Observe the thread-like appendages (**elaters**) of the spores.
6. Make drawings: (*a*) a distal end view of a typical sporophyl; (*b*) a side view of a sporophyl; (*c*) one or more spores showing the elaters closed and extended; (*d*) a side view of a strobilus.

C. Life Problems.

1. Does it live more than one year? Why?
2. Are the leaves more or less important in the work of photosynthesis (carbonfixation) than the stem? Why?
3. What conditions of soil favor the growth of horsetails? Why?
4. There are many related forms. How do they differ in general appearance from the one studied?
5. Of what use are horsetails?
6. How does its life history differ from that of the fern?

STUDY 15.

A LYCOPOD. *Selaginella.*

A. The Vegetative Portion.

1. What is the position, form, and method of branching of the stem?
2. How many sizes of leaves? Why?
3. Study the form and arrangement of the leaves.
4. Draw and describe the leaves.
5. What is the origin and form of the roots? Make a drawing to illustrate.

B. The Reproductive Portion (or Leafy Spike; the Strobilus).

1. How do the leaves differ in form and arrangement from those of the vegetative portion?
2. Find sporangia in the upper angles of the leaves. Where are they situated, and how do their contents (spores) differ in relative size and number? The smaller are **microspores**, the larger are **megaspores**.
3. Make a diagram of a longitudinal sectional view of a strobilus.

C. Life Problems.

1. What advantage is the creeping position?
2. What seems to be the cause for such forms and arrangements of its leaves?
3. How does it multiply?
4. What is its life history?
5. What is the purpose of the two sizes of spores (**heterospory**)?

STUDY 16.

A SEED PLANT. THE PINE. *A Gymnosperm.*

A. The Vegetative Shoot.

1. The cause of roughness on the main stem is **leaf scales.** What is their arrangement and what is found growing in the distal angle of some of them? What is the meaning of the occasional zones of scales?
2. The leaves are borne on small (**dwarf**) branches. What protection is there at their bases? How do young and mature leaves differ? What is the number, position, and arrangement of the leaves on a dwarf branch?
3. What is the general form of an entire leaf, also that of a cross-section? With m. find the **stomates** and observe their abundance, location, and arrangement.
4. Make a drawing of a dwarf branch and its leaves.
5. With l.p. study a cross-section of a leaf. Observe the epidermis, **mesophyl** (green tissue) containing scattered **resin ducts,** and in the center a vein having two inclosed **vascular bundles.** Make drawing.
6. With m. study a cross-section of a two- or three-year-old stem. Observe the **pith, wood,** and included **medullary** rays, and the **bark** which contains resin ducts in its green (middle) layer. What is

the explanation of the rings in the wood portion? Make a drawing (del. 3 in.) showing details of a quadrant.

B. The Reproductive Shoots. (Cones or Strobili.)

1. How do the two kinds of this year's growth differ as to number, position, size, and form?
2. Study a microsporophyl (**pollen**) bearing shoot which has been cut to show the distal half in longi-section and find a central axis bearing the sporophyls (**stamens**). With m. study a stamen to find a proximal stalk (**filament**) and sporangia (**pollen sacs**). Make proximal surface and edge view drawings of a stamen and name its parts, also a drawing of the entire shoot as prepared.
3. With l.p. study some pollen and find the two thin walled expansions (**wings**), also the one or more celled body. Draw and designate parts.
4. Make a drawing of this year's shoot, showing microsporophyl clusters.
5. Study a yearling cone which has been cut longitudinally. On the cut surface find the central axis which bears sporophyls (**carpels**). In the axils (distal angles) of the carpels, find the **ovules** each of which contains a sporangium.
6. On the outer surface of the cone find and explain the shape and arrangement of the distal ends of the carpels.
7. Make one or more drawings to show the structure of the outer and the cut surfaces (del. 2 in.) and name the parts.
8. Study a carpel of a two-year-old cone to find the number, position, and parts of the developed

ovules (seeds). Why do the seeds have wings? Make a drawing of each surface of a seed-bearing carpel and designate all its parts.

9. Study a longi-section of the seed body and note the form and position of the **embryo** (young sporophyte), also the **endosperm** and seed-coat (**testa**). Make a drawing and show all its parts.
10. In a this year's cone observe the relation of the carpels. Make a sketch to show its form and its relation to the branch. Study and explain the position of the cones of various years.

C. Life Problems.

1. What is the advantage in having "evergreen" narrow leaves?
2. What is the origin and purpose of the resin?
3. Why is the pollen so abundant?
4. How does the pollen reach the ovule?
5. What is the advantage of two kinds of shoots?
6. Why is pine lumber so desirable?
7. Where are "cone-bearing" trees found in greatest abundance? Why?

STUDY 17.

A SEED PLANT. *An Angiosperm.*

A. The Entire Plant Body.

1. Observe its size. Is it an **herb**, **shrub**, or **tree**?
2. What is its direction and method of growth?
3. What evidence is there that it lives one or more years (**annual**, **biennial**, or **perennial**)?

B. The Vegetative Shoot.

(a) *The Root System.*

1. Study the origin and form of the roots.
2. Make a drawing of the root system.

(b) *The Stem.*

1. Is there an underground stem? If so, what is its form? Why?
2. Is the above-ground stem simple or branched?
3. Do the internodes vary in length? If so, where? Why?
4. Is it smooth or rough, and if the latter, what causes the roughness?
5. With m. study a cross-section to find the arrangement of the wood bundles. Make a drawing to show its parts.

(c) *The Leaves.*

1. Are they stalked or sessile?
2. What is their form?

3. Do they vary in size? If so, where? Why?
4. What is the method of veining (venation)?
5. Compare the two surfaces as to color, smoothness, and presence of hair.
6. What is their arrangement? Why?
7. Are there any leaf modifications? If so, what, where, and why?
8. Draw an entire leaf and designate its parts, also two or more internodes of the stem, showing its surface characters and the leaf attachments.

C. The Reproductive Shoots. (Flowers.)

1. Are the **flowers** solitary or in clusters? If the latter, what is their arrangement (**inflorescence**)?
2. Is an individual flower sessile or stalked? Why?
3. The stalk of a solitary flower and the main axis of a cluster are **peduncles**. The stalk of an individual flower in a cluster is a **pedicel**. Which is present?
4. Are modified leaves (**bracts**) found at the base of the peduncles or pedicels?
5. The floral envelope consists of an outer series (**sepals**) and an inner series (**petals**). The **essential** parts are the stamens situated next within, and in the center, one or more pistils each consisting of one or more carpels.
6. Does each flower contain stamens and pistils? If so, they are **perfect**. But if not, are the **imperfect** flowers on the same or different plants? Why?
7. Study the number, form, color, and arrangement of the floral envelopes. Are any or all of these parts separate or united? Are the sepals and petals respectively alike in form and place of attachment? If not, what are the modifications?

Draw one of each if alike and separate, also any modification of form or union.

8. Study the number, length (relative), and arrangement of the stamens. Draw and designate the parts of a stamen, also any variation in length and union, if apparent.
9. Study the number, form, and arrangement of the pistils. If more than one, are they entirely separate? Draw (*a*) a pistil; (*b*) sectional views of the **ovulary** (ovule-bearing part) showing one or more cells (ovule chambers) and the place of attachment (**placenta**) of the ovules.
10. Make longitudinal and transverse diagrams of a flower, also a diagram of the inflorescence.

PART II.

GROUP V. SPERMATOPHYTES. SEED PLANTS.

STUDY 1.

SEEDS AND SEEDLINGS.

(*a*) BEAN OR PUMPKIN.

A. External Structure.

1. How does the seed differ in an edge and a side view?
2. Where is the scar (**hilum**) and what is its purpose?
3. Find two other small markings. How are they situated with reference to the hilum? One, a minute opening, is the **micropyle**; the other, a small blister-like elevation, is the **chalaza.**
4. Make drawings of a side view and of the **hilum** margin, designating all parts.

B. Internal Structure.

1. Cut open the seed-coat (**testa**) along the margin opposite to the hilum and carefully remove. What form has this coat and what is its use? What relation do hilum, micropyle, and chalaza have to it?
2. Find the small cup-shaped structure on the inner surface of the testa and discover what fits into it; with needle find into what it opens.

3. The entire structure within the seed-coat is the **embryo.**
4. To what are the two large structures (**seed-leaves** or **cotyledons**) attached? The small leaf-like structures constitute the **plumule.** The small stem to which all are attached is the **caulicle** or **hypocotyl.**
5. The place of leaf attachment is a **node.** The portion of the stem between two nodes is an **internode.** How many of each are present? The end of the stem opposite the plumule is the **radicle** or **root** end.
6. With the cotyledons spread apart and properly attached, draw (x 2) and designate all structures.

(*b*) THE CORN SEED.

A. External Structure.

1. The small structure by which the seed was attached to the cob is the **funiculus.** What is its form?
2. How do side and edge views differ?
3. How do the ends compare?
4. The lighter colored elliptical area on one side is the embryo. The large white or yellowish portion is the **endosperm.**
5. Make an embryo side view drawing (del. 1 in.) and designate all structures.

B. Internal Structure.

1. Remove the funiculus and find the hilum. What is its form?
2. Remove the testa from the embryo surface. Observe the one large flat cotyledon(?) (**scutellum**) and the small caulicle to which it is attached on the outer surface. Find the radicle end and the plumule (**apical bud**) end.

3. With the scutellum slightly spread, draw (del. 1 in.) and designate all regions of the embryo.
4. Split the seed longitudinally and, if possible, split the caulicle also; with m. study both ends of the caulicle and find how they differ.
5. Make a drawing (del. 1 in.) of one of the cut surfaces and designate all structures.
6. Make a drawing of a transverse section through the apical bud (del. $\frac{1}{2}$ in.) and designate the structures.

(*c*) COMPARATIVE STUDY OF OTHER SEEDS.

Make such drawings and notes as will clearly indicate the results of your studies, using the terms learned in sections (A) and (B).

(*d*) BEGINNING GROWTH (Germination?) AND COMPOSITION OF SEEDS.

A. Seedlings.

Have seedlings showing different stages of growth.

1. Observe the parts and designate them in terms of the study of seeds.
2. To what extent has the radicle end of the caulicle developed a root system?
3. To what extent have the cotyledons, plumule, or apical bud developed into the leafy shoot?
4. What directions have the shoot and root assumed? Why?

Experiments 21, 22, 23.

5. What portions of the seed are still attached? Why?
6. Have any of the parts become green? If so, which?
7. Make a careful drawing of each seedling in its normal position of growth and name the various parts.

B. Life Problems.

1. What and where is the first food of the seedling?

   Experiments 1, 3, 5, 6, and 7.

2. When and to what extent are exterior plant foods (**soils**) necessary? Why?

   Experiments 2, 3, and 4.

3. How do differences in moisture, temperature, air, and light affect growth?

   Experiments, with data to demonstrate, 1, 3, 4, 19, and 22.

4. As growth begins, what changes occur in (*a*) volume, (*b*) gases, (*c*) temperature, and (*d*) composition?

   Experiments 5, 8, 12, and 24.

5. Of what substances are seeds composed?

   Experiments 5, 6, and 7.

6. Do dry seeds increase in volume when supplied with water?

   Experiment 8.

7. After beans and some other seeds have been in water for a short time, why is the testa wrinkled? After further soaking, why does the testa become smooth?

   Experiment 8.

STUDY 2.

ROOTS AND THEIR MODIFICATIONS.

A. Fibrous Roots.

Desirable specimens are seedlings of the radish, bean, corn, oat, etc.

1. The large single root which continues the radicle end of the caulicle in the bean, corn, and other seeds is a **primary root,** which may or may not have branches. The cluster of roots having their origin from the radicle end of the caulicle in the oat seed are **multiple** primary roots. Those roots having their origin from any other part of the plant body than the radicle end of the caulicle, excepting regular branches of primary roots, are **secondary** roots.
2. With m. study young roots which have not been growing in soil. What is the form of the tip (**root cap**)? Why?
3. Where are the minute structures (**root hairs**) found most abundantly?
4. Make the necessary drawings to show the result of study.
5. With l.p. study the root cap. What is its structure?
6. The outer layer of cells of the root is the epidermis, the central portion is the **central cylinder** (**stele**), and between these is the **cortex.** From which portion do the root hairs have their origin?

7. What is the form and structure of the root hairs? How are they related to soil particles?
8. Make a drawing of a young root to show parts as named in 5, 6, and 7.
9. Study a cross-section of an older portion of a root. Draw and designate its parts.

B. Storage Roots.

1. In the parsnip, turnip, and sweet potato, how do the forms differ? Do soil conditions probably produce such variations? If so, how?
2. How do storage and fibrous roots differ?
3. Are they spherical, elliptical, or conical in form?
4. Draw and name the forms.
5. Of what does the food storage consist?

Experiments 5 and 7.

C. Life Problems.

1. How and why does the root system penetrate the soil?
2. How and why does soil cling to the roots?
3. What must be the condition of exterior food material (**nutriment**) to be usable?
4. Where is the region for the upward path of nutriment?

Experiment 11.

5. Why do plants have different forms of roots?
6. What is the origin and purpose of the food material in storage roots?
7. Where does the linear growth of a root occur? Why?

Experiment 20.

8. What is the origin and purpose of the acid secretion by roots?

Experiment 12.

9. The older roots of many plants contract in length. Of what advantage can this be?
10. Of what advantage are **aerial** roots?
11. Why do many trees growing in swamps have much of their root system near the surface?
12. What is the origin and purpose of the root tubercles of some plants?
13. How are some plants propagated by their roots, *e.g.* sweet potato and locust tree?
14. How do gravity, moisture, and light affect the growth and direction of roots?

Experiments 21 and 23.

15. Of what economic importance are roots?
16. What is the purpose of "root pressure," and is it always apparent? Why?

Experiment 16.

STUDY 3.

STEMS AND THEIR MODIFICATIONS.

A.

(*a*) (Desirable material for typical stems are corn and asparagus, smilax, and other woody stems which will show various bud arrangements.)

1. Find one or more scars at each node of various specimens. What causes them?
2. How are the scars related to each other?
3. What is the position of the buds with reference to the scars?
4. How do the internodes compare in length on the same and different stems?
5. In woody stems observe **zones** of scars at irregular intervals. What is their origin? What do they signify as to linear growth?
6. Compare these intervals on the same stem and on stems of different plants. What conclusions do you draw from this comparison?
7. The small speck-like structures on the internodal surface are breathing pores called **lenticels**. What is their form and relative number?
8. What is their form on stems of different years' growth? Why?
9. Are the lenticels closed or open?
10. In what respect do **apical** and **lateral** buds differ?
11. How and why are winter buds protected? Into what will they develop?

12. What is the relation of the branches to the leaf scars?
13. Make drawings showing the results of study from 1 to 12 inclusive.
14. Examine the cut ends of specimens which show **bark, wood,** and **pith** distinctly. Draw and designate all parts.
15. In a transversely cut end of a woody stem two or more years old, with m. endeavor to explain the cause of the rings found in the wood. The radial lines of the wood are called **medullary (pith) rays.** Where do they begin and terminate? Draw and name parts.
16. In a thin cross-section of a young woody stem, with l.p. and h.p. note how the **outer, middle,** and **inner** layers of the bark compare in structure and color. What is the purpose of each?
17. How do the cells of the wood and pith rays differ?
18. Make a drawing of a quadrant and designate its parts.
19. In a cross-section of Corn, Asparagus, or Smilax compare the arrangement of its tissues with those already studied. Draw and name its parts. Plants with this type of stem are **monocotyledons** and those first studied are **dicotyledons.**
20. In a longi-section of a woody stem and its branch trace the tissues of the branch to their origin in the stem. Make drawing to illustrate.
21. In a longi-section of a stem and **leaf stalk** find the origin of the leaf tissues. On the basis of this study explain the "dots" found in some leaf scars, as in Buckeye and Sumach.

(*b*) Desirable material for plant stem modifications: stems of timothy hay, wheat, or oats, Morning Glory and Virginia Creeper, Rose and Cactus, Hawthorn or Honey Locust, Potato, Onion, some rhizome, and any solid bulb.

1. Stem of a grass or grain.
   How do the nodes of these stems compare with those of other forms already studied? Is the stem hollow or solid? Why?
2. Morning Glory or Climbing Bean.
   Is the stem rigid enough to support itself in an upright position? If not, how does it grow? Why?
   Do they always twine about a support in the same direction? Why? Sketch.
3. Virginia Creeper and Grape-vine.
   How do these accomplish climbing? These slender, more or less coiled stem modifications are **tendrils**. How do they differ? How and why are the tendrils coiled between the plant and its support? Draw a portion of a stem with its tendrils.
4. Hawthorn or Honey Locust and Rose.
   What is the evidence that thorns are modified branches? What is their purpose? How do the prickles of the rose differ from the thorns as to origin, size, and distribution. Make sketches.
5. Cactus, Potato, some rhizome, and any solid bulb.
   Are leaf scars, buds, or any form of leaf apparent in each? What is the purpose of the form of stem in each of these plants? Draw and name parts.
6. Onions or Lily bulb in longi-section.
   Where is its stem? Are its internodes long or short? Is the bulb all stem structure? In what

part is its food storage? Are its roots fibrous or storage, and what is their origin?

B. Life Problems.

1. What is the purpose of plant stems?
2. Do all stems assume the same direction in growth? Why?
3. Where does the linear growth occur?

Experiment 20.

4. Where and how do stems increase in the transverse diameter?
5. Where are the upward and downward paths of the sap?

Experiment 11.

6. What is the destiny of winter buds?
7. What is the purpose of branching?
8. What is the purpose of various stem modifications?
9. Explain the presence and hardness of knots in lumber.
10. What is the purpose of pruning?
11. Explain pollarding of various trees.
12. Of what advantage is it to grass stems in being hollow?
13. Explain plant propagation by stems.
14. What are the economic products of stems?
15. How do gravity and light affect the growth of stems?

Experiments 21 and 22.

16. How do annual, biennial, and perennial stems differ?

STUDY 4.

LEAVES AND THEIR MODIFICATIONS.

(A **Geranium** leaf attached to a small portion of stem is desirable material.)

A. Type Foliage Leaf.

1. The leaf stalk (**petiole**) bears upon its distal end the expanded portion (**lamina**, or blade), also at its proximal end two smaller expanded portions (**stipules**). Note the structure, form, and color of each.
2. Note the differences in the under (**dorsal**) and the upper (**ventral**) surface of the lamina. To what are they due?
3. Study the origin and distribution of the veins of the lamina. Use m. Why are they so branching?
4. With m. observe the distribution and forms of hairs. Of what advantage are they?
5. Make the necessary drawings to demonstrate the results of your study.
6. By tearing the leaf toward one side the epidermis of both surfaces may be obtained. With l.p. and h.p. study the form and arrangement of the cells, hairs, and stomates.
7. Study the color and contents of the epidermal cells, also the number, form, and color of the guard cells of the stomates.

8. What is the origin and structure of the hairs? How do they differ? Why?
9. Draw and designate all parts, showing the results of the study in (6), (7), and (8).
10. How does the epidermis of the dorsal and ventral surfaces differ, especially with reference to stomates and hairs?
11. With l.p. and h.p. study a thin transverse section in the region of a vein. Study the form and structure of the vein. Near which surface is it? Why?
12. How do the green cells (**mesophyl**) differ as to form and arrangement? If elongated, vertically arranged cells (**palisades**) are present, near which surface are they? Why?
13. Are there small chambers (**intercellular spaces**) between the cells? If so, what is their purpose? To what do they lead? Why? Make a drawing and designate the results of your study.

B. Leaf Variations.

1. In the material provided, find leaves without stipules, others without petioles (**sessile**), and others with their blades divided into wholly separate pieces (**leaflets**); such leaves are **compound**. Make drawings of attached leaves to show these forms.
2. Study the specimens for variation in venation. Do the veins make a prominent net-work (**netted** venation), or are they mainly parallel (**parallel** venation)?
3. Of the netted venation forms, do the main veins arise from the base (**palmately netted**), or do they arise from a midrib (**pinnately netted**)? Make drawings to show the forms of venation.

C. Prominent Leaf Modifications.

1. Leaves of Sweet or Garden Pea.
   Is the leaf simple or compound? What part has become the tendril? Draw and show all its parts.
2. Common Locust, Barberry, and Cactus.
   What parts have become **spines**? Make drawings of stem portions showing spines.
3. Scales of winter buds and on leafy shoots and underground stems.
   What parts of the leaf are present? What is their structure and arrangement? What is their purpose?
4. Storage forms.
   Onion or Lily, Cotyledons of Bean or Pea.
   What parts of the leaf are present, and what forms have they assumed?
5. What other leaf modifications are to be found?

D. Life Problems.

1. Three important functions of foliage leaves are (*a*) **transpiration,** (*b*) **respiration,** and (*c*) **photosynthesis.**

(*a*) What is the evidence and purpose of the loss of water from the leaf surface (transpiration)?

Experiment 15.

Explain "wilting" and how turgor may be restored.
How is transpiration regulated? Why?
What is the origin and purpose of the "dew" on plants?

Experiment 18.

How does covering of plants assist in preventing them from being killed by "frost"?

(*b*) What is the evidence of the inhalation of oxygen and the exhalation of carbon dioxide (respiration)?

Experiments 3 and 12.

What is the source of the oxygen supply in water and in land forms?

(*c*) Photosynthesis consists in the formation of carbohydrate (CH_2O) food from water (H_2O) and carbon-dioxide (CO_2) by **chloroplasts** (chlorophyl bodies) in the presence of light.

How can it be proved that oxygen is liberated during photosynthesis work?

Experiment 13.

How can it be proved that CO_2 is necessary for photosynthesis work?

Experiment 4.

What is the evidence of visible carbohydrate food (starch) production?

Experiments 13 and 5.

How can it be proved that light is necessary?

Experiment 13.

2. How is leaf arrangement associated with light relation?
3. In the light relation of leaves, what is the purpose of the petiole, and how is it modified?
4. In water plants, why do the leaves which are above and below the surface of the water differ so much in form?
5. What is the purpose of leaf reduction in the cactus?
6. Where is photosynthesis performed in the cactus?
7. What is the meaning of the thickened leaves in the century and cabbage plants?
8. Why do some plants have leaves in the form of pitchers and "fly traps"?

9. Where is the path of the nutriment to the leaf mesophyl?

Experiment 11.

10. How does the evaporation of the transpiration affect the upward movement of nutriment (sap)?

Experiment 17.

11. What is the source of odor of some leaves?
12. Explain color variations of foliage leaves.
13. How do hairs differ in color, form, and structure, and what is their purpose?

STUDY 5.

FLOWERS AND SOME MODIFICATIONS.

A. Type Flower.

1. The flower stalk (**peduncle** or **pedicel**) is usually more or less enlarged at its distal end, forming a receptacle upon which the floral parts are borne.
2. The lower or outer parts are **sepals** which together constitute the **calyx**. The next structures are the **petals** which together constitute the **corolla**. What is the number, form, and color of the sepals and petals? What is their relation to each other? Draw one of each.
3. The remaining parts are "**essential,**" and consist of an outer series, the **stamens,** and in the center one or more **pistils.**

   A stamen (**sporophyl**) consists of a slender stalk, the **filament,** and a distal enlargement, the **anther**; the anther bears one or more sporangia containing **pollen** (**microspores**). A pistil consists of one or more sporophyls (**carpels**); the basal enlargement of the pistil is the **ovulary** (ovary?), and terminates in one or more distal sticky portions, the **stigmas**, the slender portion which connects a stigma with the ovulary, if present, is the **style.** What is the number, form, and arrangement of both stamens and pistils? Make drawings and designate all parts.

4. Make a cross-section of an ovulary and with m. note the number of carpels and their relation, also the number, position, and place of attachment (**placenta**) of small bodies, the **ovules**, each of which contains a sporangium. Make a drawing and designate parts.
5. Make transverse and longitudinal sectional diagrams of the flower, showing the number, general form, and relation of all floral parts.
6. Write a floral formula, which consists of the parts arranged in regular order, the number of each series being placed in its proper position. A line above the number indicates the union of like parts, and a line below connecting two series indicates union of unlike parts, *e.g.*: —

SEPALS	PETALS	STAMENS	CARPELS
$\widehat{5}$	$\widehat{5}$	$\underset{\smile}{5}$	$\widehat{2}$

B. Some Modifications.

1. Study other flowers and compare with the type flower.
   (*a*) Are all the series present (**complete**)? If not, which are lacking?
   (*b*) Are the petals alike in form and size (**regular**) or unlike (**irregular**)?
   (*c*) Are both stamens and pistils present (**perfect**)?
   (*d*) Are the petals free from (**polypetalous**) or united to each other (**sympetalous**)?
   (*e*) Are all the parts borne on the receptacle? If not, to what are they attached?
2. Make drawings and diagrams as indicated in the Type Flower and write the floral formula.

C. Life Problems.

1. What is the meaning of the bright colors, the odors, and the nectaries of flowers?
2. **Pollenation** is the transfer of pollen to the stigma. In how many ways is it accomplished? In each flower studied endeavor to find how this is done.
3. In various flowers what devices favor cross pollenation?
4. Flowers are situated in various positions and have various forms. Why?
5. Do the various parts continue to occupy the same relative position? Why?
6. What is the purpose and destiny of each floral part?

STUDY 6.

TYPICAL FRUITS.

A. The Composition and Texture of Fruits.

Study each of the following specimens from whole fruits and prepared sections and explain the floral origin and structure of their parts. Make notes and drawings to show the results of study.

1. The Tomato, Gooseberry, and Orange are **berries.**
2. Peaches and Plums are **drupes.**
3. The Apple is a **pome.**
4. Dandelion and Maple seeds are **akenes.**
5. Hickory nuts and Filberts are **nuts.**
6. Poppy and Wild Cucumber fruits are **capsules.**
7. Corn, Wheat, and Oats are **grains.**
8. Peas and Beans in pods are **legumes.**
9. A Raspberry is an **aggregate** fruit.
10. A Strawberry is an **accessory** fruit.
11. A Pine Apple is a **multiple** fruit.

B. Some Additional Devices for the Dissemination of Seeds.

1. Study winged fruits, *e.g.* Maple or Ash and Linden.
2. Burs, *e.g.* Cocklebur and Burdock.
3. Tufted seeds, *e.g.* Thistle and Milkweed.
4. Make drawings to show the devices for seed distribution and explain their usefulness.

5. Study numerous other fruits and compare them with the types already studied.

Summarize all fruits studied according to the following

SUMMARY.

COMMON NAME.	FRUIT NAME.	FROM WHAT FLORAL PART.	PLACE AND KIND OF FOOD STORAGE.	DEVICE FOR DISTRIBUTION.	POSITION OF SEED.

C. Life Problems.

1. What is the purpose of fleshy fruits?
2. How many natural means of seed dissemination are there?
3. In what two ways may animals be the carriers of seeds?
4. What are the two types of fruit modifications which aid in wind dissemination?
5. How may plants scatter their own seeds?
6. What is the purpose of seed dissemination?
7. Why do plants produce so many seeds?
8. How do islands near a coast have plants like the mainland, while islands in mid-ocean are apt to have a specialized flora?
9. Do plants migrate? If so, how? Why?
10. Why is the flora of Japan so much more like our own than that of Europe?

STUDY 7.

AN ANGIOSPERM IN FLOWER.

A. The Entire Plant Body.

1. Observe its size. Is it an **herb, shrub,** or **tree**?
2. What is its direction and method of growth?
3. What evidence is there that it lives one or more years (**annual, biennial,** and **perennial**)?

B. The Vegetative Shoot.

(a) *The Root System.*

1. Study the origin and form of the roots.
2. The plant has what kind of roots?
3. Make a drawing of the root system.

(b) *The Stem.*

1. Is there an underground stem? If so, what is its form? Why?
2. Is the main stem simple or branched?
3. Do the internodes vary in length? If so, where? Why?
4. Is it smooth or rough, and, if the latter, what causes the roughness?
5. With m. study a cross-section to find the arrangement of the wood bundles. Make a drawing to show its parts.

(c) *The Leaves.*

1. Are they stalked or sessile?
2. Are they simple or compound, and what is their form?
3. Do they vary in size? If so, where? Why?
4. What is their venation?
5. Compare the two surfaces as to color, smoothness, and presence of hair.
6. What is their arrangement? Why?
7. Are there any leaf modifications? If so, what, where, and why?
8. Draw two or more internodes of the stem, showing its surface characters, leaf attachments, and form of leaf, designating all parts.

(d) *The Reproductive Shoots.* (*Flowers.*)

1. Are the flowers solitary or in clusters? If the latter, what is their arrangement (**inflorescence**)?
2. Is an individual flower sessile or stalked? Why?
3. Are modified leaves (**bracts**) found at the base of the peduncles or pedicels?
4. Does each flower contain stamens and pistils? If not, are the imperfect flowers on the same or different plants? Why?
5. Study the number, form, color, and arrangement of the floral envelopes. Are any or all of these parts separate or united? Are the sepals and petals respectively alike in form? Draw one of each if alike and separate, also any modification of form or union.
6. Study the number, length (relative), and arrangement of the stamens. Draw and designate the

parts of a stamen, also any variation in length and union, if apparent.

7. Study the number, form, and arrangement of the pistils. If more than one, are they entirely separate? Draw and designate the parts of a pistil, also sectional views of the ovulary showing one or more cells (ovule chambers), also the place of the ovule attachment (placenta).
8. If the entire plant is small enough, make a careful drawing of it, or prepare a specimen properly mounted.
9. Write floral formula.
10. By means of an analytical key, *e.g.* Appendix III, determine the classification of the plant as to its

Family ——
Scientific name { Genus ——
Species ——
Common name ——

C. Life Problems.

NOTE. — A few suggestive "Life Problems" are given, and others should be made by teacher and pupil to fit each plant studied. In the study of entire plants, life problems should be especially emphasized.

1. What is the habitat of the plant? Why?
2. Are there any modifications in the plant structures to fit it to the conditions where it is found?
3. Explain the form and structure of the root, stem, leaf, and flower.
4. Why is the plant or its parts smooth or hairy?
5. Why are the leaves and flowers arranged as you find them?

6. Are the flowers and floral parts arranged to favor self- or cross-pollenation?
7. If the latter, what special devices are there to favor cross-pollenation?
8. What is the agent of pollenation?
9. What is the form and structure of the fruit? Why?
10. How are the seeds disseminated? If there is a special device for this, explain fully.
11. Ask yourself the meaning of everything, and especially as to why plants vary so much, and how the variations aid the plant in its struggle for existence.
12. Why is this plant scattered over a greater or less range than plants previously studied?
13. What is the relation of the plant to the animals found in the same locality?
14. Is the plant or any of its parts useful to man? How?
15. Is the plant or any of its parts harmful to man? How?

NOTE. — In a similar way study numerous other plants.

APPENDIX I.

EXPERIMENTS AND DEMONSTRATIONS TO SHOW THE LIFE PHENOMENA OF PLANTS.

In the part of this book devoted to the consideration of different plants, the word "experiment" frequently appears followed by a number or numbers. Each experiment has a corresponding number to that in the plant study. In all cases diagrams should be made of the apparatus used, with explanations of results.

I. PLANT FOODS AND THEIR COMPOSITION.

EXPERIMENT 1. TO SHOW THE NECESSITY OF WATER.

(*a*) In germinating seeds.

Place a quantity of oats, peas, or other seeds in a dish under a bell jar, keeping them dry. Under a second bell jar place similar seeds, but moisten occasionally. It will require but three or four days to obtain results.

Or between two rectangular glass plates place several thicknesses of blotting paper, and scatter a number of oat seeds on the paper. Hold the plates together with spring clips. Stand the plates in an upright position in enough water to keep the paper moist, and prepare a similar set which is to be kept dry.

(*b*) In ordinary plants.

Withhold water from a plant growing in a flower-pot, and note results.

EXPERIMENT 2. TO SHOW THE NECESSITY OF SOIL SALTS.

(*a*) With algæ.

Place some alga, as spirogyra, in a jar of distilled water. Another portion of the same alga is to be put into common hydrant or well water, and a third portion is to be placed in a nutrient solution, having the following composition: —

Water	1000 c.c.
Potassium nitrate	.5 gr.
Sodium chloride	.5 gr.
Calcium sulphate	.5 gr.
Magnesium sulphate	.5 gr.
Calcium phosphate	.5 gr.

Place the three jars in the same conditions, and observe the results at the end of several days.

(*b*) With seedlings.

Germinate seeds of peas or corn in a moist chamber, and when the root systems are well developed, carefully select three of a kind as nearly equal in development as possible; place each on a piece of netting, stretched over a wide-mouthed bottle containing distilled or common water, or nutrient solution, as the case may be. See that the roots pass through the netting and enter the solution. Cover each with a bell jar, and await results.

N.B. All will grow equally well for some time.

EXPERIMENT 3. TO SHOW THE NECESSITY OF OXYGEN.

(*a*) In algæ.

Use two large wide-mouthed bottles; in one have some water which has been boiled for some time and cooled, in the other have ordinary water containing air.

Into each place a small quantity of a vigorous filamentous alga. Pass carbon dioxide but no oxygen into the boiled water, and after a few days observe which has died, and explain.

(*b*) In fungi and germinating seeds.

Prepare three U-tubes and three slightly larger-sized bottles. Half fill the bottles respectively with water, strong solution of caustic potash, and saturated solution of pyrogallic acid in caustic potash. Place in one arm of each U-tube the fungus or germinating seeds. A wad of moist cotton should be placed below the seeds, and then the lower end of each U-tube should be closed with closely fitted rubber stoppers.

Keep the inner portion of the rest of the tubes dry; then place the open ends of the tubes into the liquids in the bottles. Caustic potash absorbs the carbon dioxide, and pyrogallic acid absorbs oxygen; with these facts in mind, after a few days, explain the observed results.

EXPERIMENT 4. TO SHOW THE NECESSITY OF CARBON DIOXIDE FOR GREEN PLANTS.

(*a*) For algæ.

Boil hydrant or well water in three large flasks, cork and cool. Leave the first flask undisturbed. Open and shake the second to introduce oxygen of the air; into the third introduce carbon dioxide and oxygen. In each flask now place a small quantity of a filamentous alga, and, after standing in the sunlight for a time, observe the difference in the evolution of a gas, which is proved by another experiment to be oxygen. Explain.

(*b*) The foliage plants.

Place a growing plant on a ground glass plate with a saucer of caustic potash to absorb the carbon dioxide, and cover with a bell jar. Seal the bell jar with glycerine or some other oil.

Place another plant in similar conditions, but do not remove the carbon dioxide from the air. After a few days test each plant for starch. Explain the difference of results.

EXPERIMENT 5. CARBOHYDRATES (Sugar and Starch).

(*a*) To test for.

If weak iodine is added to starch, especially in solution, a bluish color will result. In testing seeds and roots, crush, boil in water, and cool before applying the iodine. Green plant parts must have been in the sunlight for some time, and it is best to remove the chlorophyl before the test is made.

Fehling's solution added to grape sugar and boiled will give a brick-red color. It is usually desirable to crush the seeds, or other hard parts, before testing.

(*b*) To show the necessity of.

To a fungus.

Place yeast in water without sugar or other food. In another vessel place yeast with water and a little sugar. Which shows growth with an evolution of a gas? Why?

To an alga in the dark.

Place an actively growing alga in a weak grape sugar solution, and another quantity of alga in distilled water. Keep both in a dark place. After several days one dies, and the other is still active. Explain results.

EXPERIMENT 6. HYDROCARBONS (Oils).

To test for.

Crush seeds, or other parts to be tested, and place in a bottle with ether; cork and allow to stand for some time. Then decant the liquid, and permit the ether to evaporate. If oil is present, it will easily be seen.

EXPERIMENT 7. PROTEIDS (Nitrogenous Substances).

(*a*) To test for.

Crush the substance to be tested. Add Millon's solution and boil. If a proteid is present, it will be denoted by a pink or reddish color or coagulum appearing in the solution.

(*b*) To show the necessity of.

Place an actively growing alga in the nutrient solution (Experiment 2) with the potassium nitrate omitted. A second quantity of alga is to be placed in the nutrient solution complete. Compare and explain results after a few days.

II. METABOLISM.

EXPERIMENT 8. TO SHOW TURGOR AND EXPLAIN FOOD ABSORPTION (Osmosis).

(*a*) Egg experiment.

Carefully remove the shell from the larger end of an egg, exposing a considerable area of the membrane. Drill a hole into the smaller end and insert a glass tube, being sure that it enters the yolk. Thoroughly seal with wax where the tube enters the shell to exclude air. Now place the larger end of the egg in a suitable vessel of water so that the latter will cover the exposed membrane. Support the tube in any convenient way. The tube ought to be two or three feet in length. Observe and explain the rise of the yolk in the tube.

(*b*) Raisin.

Place raisins in water and observe that they swell and become several times larger than at first. Why?

(*c*) Seeds.

Place beans in a thin test-tube (or better use a thin-walled glass vial with screw top) and then fill the tube with water; securely tie in a cork, and examine the next day. Explain the wrinkling of the seed at first, and later the smoothness of the seed and the breaking of the tube.

EXPERIMENT 9. TO SHOW THE CAUSE OF FLACCIDITY (Wilting).

(*a*) Into a 5 per cent solution of common salt place some longitudinal sections of a fresh rhubarb petiole, or any other

turgid young tissue. After a few hours in what direction, with reference to the epidermis, have the sections become coiled, and why are they so limber? How does similar material respond to the effect of ordinary water?

Treat some filaments of an alga or a fungus in the same way and with l.p. and h.p. study the results.

(*b*) Use a strong sugar solution (5 per cent or more) and note the effect on yeast plants, other fungi, and some alga. Explain the results.

EXPERIMENT 10. TO SHOW FOOD DIGESTION.

Of Starch.

With Fehling's solution, as in Experiment 5, test some starch to prove the absence of sugar. If no sugar is present, boil some of the starch in pure water and permit it to cool. To obtain a plant **enzyme**, crush some malt and let it soak in pure water for one or two hours and then filter. Test the filtrate with Fehling's solution to prove the absence of sugar; add this to the boiled starch, and keep warm. After some time test with Fehling's solution to show the presence of sugar. What caused it?

EXPERIMENT 11. TO SHOW FOOD DISTRIBUTION (Circulation).

(a) *The Path of the Upward Movement of Nutriment (Sap).*

Take some entire plant with a well-marked tap root, *e.g.* a small parsnip, also a young leafy shoot that has had a narrow zone of the bark removed. Cut off the root tip and the lower end of the shoot and place each in a colored solution (Eosine in water or common red ink) for a number of hours. By sections of the root and stem and the examination of the leaves, observe the path of the colored fluid.

A tree may be girdled (*i.e.* a ring of bark removed) in the spring and it will produce leaves and live during the season Why? It will die the next fall or winter. Why?

(b) *The Path of the Downward Movement of Nutriment.*

Take two leafy willow twigs of equal size, and at equal distances from cut ends remove rings of bark of the same size. Place each in a vessel of water, so that in one the water level is below the girdle and in the other it is above the girdle. After some days observe the difference in root formation, and explain the larger roots above the girdle in the second specimen.

EXPERIMENT 12. TO SHOW RESPIRATION.

(*a*) For oxygen inhalation consult Experiment 3.
(*b*) For carbon dioxide exhalation in —

(1) Algæ and green plants in darkness.

Place vigorously growing algæ or oats in jars in the evening, and tightly stopper the bottles. In the morning plunge a lighted taper in each jar. It is extinguished. Why?

(2) Growing yeast.

In a jar containing vigorously growing yeast, note the evolution of a gas; close the jar and allow it to collect, and test by a lighted taper. Or pass this gas through lime water. What is the explanation?

(3) Growing seeds.

Take a number of growing seeds and place them in a bottle and close with a rubber stopper. After some hours test with taper or lime water and observe results.

(4) Growing roots.

Grow some seèdlings in earth on a marble slab. After a couple of weeks, observe the etching of the marble where the roots came in contact with it. Carbonic acid has been thrown off by the roots and has dissolved portions of the marble.

EXPERIMENT 13. TO SHOW PHOTOSYNTHESIS.

(*a*) Algæ or aquatic plants growing in the light.

(1) Liberation of oxygen.

Place a vigorous alga or other water plant, as Elodea, in a good light position and observe the bubbles of gas that form and rise to the surface of the water. By means of an inverted funnel over which a test-tube filled with water is placed collect the gas. When the tube is filled, insert into lower end a glowing match and observe the result. This is a test for oxygen.

(2) The storage of starch.

Examine spirogyra that has been for some time in the dark and test it for starch. Place the alga in the light, and after some hours test again for starch. What results do you obtain, and how do you explain them?

(*b*) Leafy shoots growing in the light.

With two small pieces of cork, by means of a pin, cover an area of the mesophyl of a growing leaf. Let it remain for about two days, and after plenty of sunlight remove the leaf and the cork, and kill the leaf tissues by boiling in water; then place the leaf in alcohol to remove the chlorophyl, after which place it in iodine solution, and the starch area will become dark. Where was there no starch storage? Why?

A vigorous leafy shoot of a geranium may be immersed in water and the gas evolution observed and tested in the same way, and the starch storage tests carried out as for the aquatic plant.

EXPERIMENT 14. TO SHOW OTHER PROTOPLASMIC PRODUCTS.

(*a*) Chlorophyl.

To strong or absolute alcohol in a bottle add some vigorous alga. Tightly cork, and in a few days observe the color of

the alga, also that of the alcohol. Separate the fluid and evaporate the alcohol in a porcelain dish, and observe the residue, which is chlorophyl.

(*b*) Gelatine.

To some nostoc or spirogyra on a glass slide add ordinary coloring matter, as black or red ink. Does the coloring matter come in contact with the cell walls? Why?

(*c*) Alcohol.

After a quantity of yeast plants have grown rapidly for some time in a flask, and have become "sour" as to odor, connect with a still and evaporate slowly. Test a small quantity of the first portion of the distillate by applying a lighted match; the burning is due to the presence of alcohol.

EXPERIMENT 15. TO SHOW TRANSPIRATION.

Take a vigorous leafy shoot and insert its cut end through a cork into a bottle of water. Cover with a bell jar, and in a short time observe the moisture on the inside of the bell jar. Explain its source. In an exposed shoot prepared in the same manner weigh from time to time, and observe loss of weight of the shoot, and explain.

EXPERIMENT 16. TO SHOW ROOT PRESSURE.

Cut off the stem of a young, actively growing plant a short distance above the soil, and fasten to the stump, by means of a rubber tube of about the same size as the stem, a glass tube at least three feet long. Into the tube pour enough water to cover the cut end of the plant, and support the whole apparatus by proper means. Observe the height to which the water rises. Does it rise from the first?

Another method is to attach a tube bent in the shape of a modified S, with the free arm of considerable length, to the cut-off stump of a plant. Fill the tube by first pouring in a little water and then mercury, so that the latter stands at the

same level in the two arms. As root pressure is manifested, the mercury will rise in the long arm, and the actual amount of pressure may be deduced by calculation.

EXPERIMENT 17. TO SHOW THE LIFTING POWER OF EVAPORATION.

To the proximal end of the vigorous leafy shoot which was removed in Experiment 16 attach a glass tube fifteen or twenty inches in length, by means of a closely fitted piece of rubber tubing. Fill the tubing with water, and invert into a vessel of mercury. From time to time observe the rise of the mercury in the glass tube, and explain the strength of this pull.

EXPERIMENT 18. TO SHOW CONDITIONS AFFECTING EVAPORATION.

Prepare a leafy shoot as in Experiment 15 and continue the experiment until the water stands in drops on the leaves. This shows the effect of an atmosphere saturated with moisture or transpiration. Explain.

After the drops have formed on the plant remove the bell jar and observe the gradual disappearance of the drops. Explain. How does variation of heat modify the results?

EXPERIMENT 19. TO SHOW HEAT PRODUCTION IN THE "GROWING SEED."

In (3) of Experiment 12 test with a thermometer the variation of temperature in the bottle as compared with the outside air.

III. GROWTH.

EXPERIMENT 20. TO SHOW THE PLACE OF GROWTH.

(*a*) In roots.

Take a well-developed clean corn seedling, and place in a thistle tube so that the primary root passes down the tube.

Cover the seed with moist cotton and insert the tube in a moist chamber. In a few days root hairs in abundance will be seen. By ink marks on the tube at regular short intervals the region of growth may be determined.

(*b*) On stems.

By ink marks placed at regular intervals on a young growing stem the region and amount of growth may be found. In grasses the upper portion of each internode must be similarly marked to obtain results. Explain.

IV. IRRITABILITY.

EXPERIMENT 21. TO SHOW THE EFFECT OF GRAVITY.

Using the material as arranged in the latter part of (*a*) in Experiment 1, arrange the plates vertically so that the roots and stems lie in a horizontal position, and after some time observe the direction of growth of the roots and shoots. Which manifest positive and which negative **geotropism?**

To vary the experiment the plant may be entirely inverted.

EXPERIMENT 22. TO SHOW THE EFFECT OF LIGHT.

(*a*) On seed germination.

Place some seeds with the same favorable conditions for growth except that some are placed in the light and others in the dark. After several days observe and explain the results.

(*b*) Place ordinary young foliage plants in the light and others in the dark. After several days observe and explain the lighter color of those growing in the dark (**etiolation**).

(*c*) Place ordinary young foliage plants in a position to receive light from but one direction. After some time observe the change of direction and position of the stem and leaves (**heliotropism**). Reverse the plant and again observe in the same way.

EXPERIMENT 23. TO SHOW THE EFFECT OF WATER.

Grow various seeds on a suspended moistened sponge; under the influence of gravity roots usually grow downward. Why do many of the roots, as shown in the experiment, grow toward and into the moist sponge, in opposition to gravity (**hydrotropism**) ?

EXPERIMENT 24. TO SHOW THE EFFECT OF TEMPERATURE.

(*a*) On germinating seeds.

Sow seeds in the same favorable conditions for growth except in temperature; some in a place of low, others in an ordinary, and still others in a place of high temperature. After several days observe and explain the results.

(*b*) Place young growing leafy plants in the same conditions as in (*a*), and in like manner observe and explain the results.

APPENDIX II.

A FIELD TRIP FOR ECOLOGICAL STUDIES OF PLANTS.

As far as possible it is a very desirable feature of plant study to go to the place where the plant lives, and observe the surrounding conditions of moisture, soil, light, and other plant forms, in this way becoming acquainted with the plant as a definite living thing, requiring a certain environment in order to most fully accomplish its life work.

Even in large cities it is possible to do some of this field work, and the result of this form of study will amply repay the time necessary. Where access to the country is at all practicable, much benefit may confidently be expected from this form of plant investigation.

In order that the method may be fully understood, an outline is presented below of an actually existing (May, 1900) field for study in the city of Chicago. The student is expected to go over the course laid out, provided with a definite route and a note-book, and is to report upon the observations made during some stated time.

A FIELD TRIP TO BOWMANVILLE.

(MAY 25, 1900.)

1. On Lincoln Avenue, north from the street-car terminus, study the small woodland on the right side. What trees are found? What herbs? At the north margin observe particu-

larly the blueberries and other rare plants. What is the land surface? What kind of soil is found? Observe the ridge and estimate its width and elevation. Can you explain it?

2. Observe the ditch of running water along the margin of the woods. What plants do you find in the water? Are they flowering plants? What do they live on?

3. In the southeast corner of the woods observe the moisture of the soil. What plants do you find? Why are there not more herbs? Examine the skunk-cabbage (the very large-leaved herb). Notice its odor. Can you find any flowers?

4. What trees are here? Do they seem to thrive? How can you tell?

5. Observe the fungi on the trunks of the trees. Explain their presence.

6. Do you observe any birds?

7. Observe the "mushrooms" on the ground. Try and find whether or not they grow directly from the soil.

8. Walk northwest. Do the plants change in kind? Why?

9. How do you account for the rich, black soil?

10. Remove some bark from a fallen tree and observe the white felted threads "mycelium" of the tree fungus. What is their purpose?

11. Observe the small area of may-apples. Why are they not everywhere?

12. What other plants grow with them?

13. Study the open, grassy place. How do the plants differ from those in the woods?

14. Note the difference in shape of the scattered trees from those in the woods. Why?

15. Explain the blackberry patch. Study the prickles.

16. What plants are found in the "patch"?

17. Examine the hawthorns and study the thorns. What use have they? Observe the odor of the flowers.

18. Observe the red honeysuckle. How is it benefited by

becoming a climber? Examine its flowers. Is there nectar? If so, where is it situated?

19. Find the "golden seal" and examine its roots. Taste its roots. They are used in medicine.

20. Study the wild "Sweet William" (Phlox). Examine its flowers carefully. Are they sympetalous or polypetalous?

21. Study the ferns. Where do they grow? Examine the underground portion. Observe young fronds. What form have they?

22. Do you find any in open, sunny places? Why?

23. Notice the spice bushes (chew bark). It is an aromatic plant.

24. Examine carefully the flowers on the steep slope, and compare them with those in the woods. Why are they so different?

25. Examine the slow-running stream and observe the water plants. Pull up a water plant and observe the spongy structure. Why? What kinds do you find?

26. Are the trees the same as before? What kind do you see?

27. Examine the willows. Why do branchlets break off so easily?

28. Why do many water plants have such large leaves?

29. Notice the very small floating duck weeds. Have they roots, stems, and leaves?

30. Gather various flowers and leaves for more careful study.

NOTE. — Numerous routes and results of field studies may be suggested; diagrams of the trips may be recorded and platted on a map of the vicinity which has been studied.

APPENDIX III.

THE DETERMINATION OF ONE HUNDRED SEED PLANTS OF NORTHEASTERN UNITED STATES.

THIS scheme for determining the names of a hundred of the more common and conspicuous plants of the northeastern portion of the United States is based primarily upon the great natural plant societies, and secondarily upon the size and general life duration. The remaining characters chosen are such as the student would most naturally and readily observe. While the key is largely artificial, yet it is hoped that the determination of a plant by its assistance will acquaint the student with it, not merely as a specimen for laboratory work, but as a living thing, having certain definite life relations. It is urged that this determinative work be preceded, as far as possible, by intelligent field work.

The key is largely self-explanatory, but for the sake of brevity, the following abbreviations have been introduced: —

= parallel veins; if this sign is absent the leaf is understood to be netted veined.

fls., flowers; *st.*, stamens; *p.*, pistil; *reg.*, regular; *irreg.*, irregular; *lvs.*, leaves; *lvs. rad.*, leaves all apparently from the root (a short stem); *lvs. com.*, leaves compound; *pi.*, 3-foliate leaves pinnately compound of three leaflets; *pa.*, 3-foliate leaves palmately compound of three leaflets; 3m. 4m. 5m., three, four, or five sepals, or petals, referring to the petals generally. The Genus is the first part and the Species is the second part of the scientific name.

The number after the plant refers to the family to which it belongs. A list of the families is given at the end of the key with a short synopsis of each to enable the student to become acquainted with the characteristics of representative groups of plants.

KEY.

Plants growing in deep or shallow water . .	HYDROPHYTES.	A
Plants growing in bogs, swamps, or marshes .	"	B
Plants growing in medium water-supply conditions (uplands)	MESOPHYTES.	C
Plants growing in very dry sandy or rocky places	XEROPHYTES.	D

A.

HERBS.

Fls. *white*,

small (1 in. or less), reg.

3 m.; st. 6; lvs. rad., oblong heart-shape . . . . . *Water Plantain.* (Alisma plantago) 2

3 m.; st. many; lvs. rad., arrow form, *Arrow Leaf.* (Sagittaria variabilis) 2

5 m.; st. many; lvs. finely divided, flaccid when taken from water . . *Water Crowfoot.* (Batrachium tricophyllum) 16

rigid " " " " (B. divaricatum)

5 m.; st. 5; p. 1; lvs. 3 foliate . . *Buck Bean.* (Menyanthes trifoliata) 35

large (3 in. or more), reg., many-petaled.

sepals pinkish; fls. strongly odorous . . . . . *Water Lily.* (Castalia odorata) 15

sepals greenish; fls. barely odorous, (C. tuberosa)

Fls. *yellow*,

small, reg.

5 m.; st. many; p. many; lvs. finely parted . . . . . *Water Crowfoot.* (Ranunculus delphinifolius) 16

small, irreg.
spurred; lvs. with bladders, floating, *Bladderworts.* 39
(Utricularia species ?)
medium (1–3 in.),
st. many; lvs. large, heart-shape . *Yellow Water Lily.* 15
(Nymphæa advena)
very large (5–10 in.),
st. many; pet. many; lvs. very large, peltate . . . . . *Lotus.* 15
(Nelumbo lutea)

Fls. *red*,
very small, crowded in racemes.
5 m.; st. 5; lvs. oblong, floating . . *Water Persicaria.* 12
(Polygonum amphibium)

Fls. *blue*,
irreg., 6 m.; st. 6; p. 1; lvs. heart-arrow form . . . . . *Pickerel Weed.* 4
(Pontederia cordata)

Fls. *green*,
very small, in spikes.
4 m.; st. 4; p. 4; lvs. submersed and floating . . . . . *Pondweeds.* 1
(Potamogeton species ?)

B.

HERBS.

Fls. *white*,
small, reg., 4 m.; st. 6; p. 1;
lvs. pi. 6–15 foliate . . . . . *Cuckoo Flower.* 20
(Cardamine pratensis)
lvs. simple; root tuberous . . . . *Cress.* 20
(C. bulbosa)
small, irreg., 3 m.; lvs. = ; st. 1; fls. many, spirally arranged, sweet scented . . . . . *Ladies' Tresses.* 10
(Gyrostachys cernua)
medium, with slipper-like lip, 3 m.; st. 2; lvs. = ; fl. solitary . . . . . *White Lady Slipper.* 10
(Cypripedium candidum)
large, with pinkish slipper-like lip, 3 m.; st. 2 . . . . . *Showy Lady Slipper.* 10
(C. reginæ)

Fls. *yellow*,
medium, petals none; sepals 5–9; st. many; p. 5–10; lvs. heart-shaped, *Marsh Marigold.* 16
(Caltha palustris)

medium, 5 m.; st. many; lvs. pi. 7–21 foliate, silvery underneath . . *Silverweed.* (Potentilla anserina) 22

Fls. *red* or *reddish*,

medium, irreg.

3 m., with a bearded lip; lvs. = ; stem from a bulb; fls. 2–6 . . . *Calopogon.* (Limordum tuberosum) 10

stem from thickened roots; fls. solitary, sweet scented . . . . *Pogonia.* (Pogonia ophioglossoides) 10

stem from a bulb; fls. solitary . . *Arethusa.* (A. bulbosa) 10

5 m., sympetalous; st. 5; p. 1; tall leafy, with milky sap; fls. many, *Cardinal Flower.* (Lobelia cardinalis) 41

medium or small, reg.

5 m.; st. many; lvs. pi. 5–7 foliate . *Marsh Fivefinger.* (Comarum palustre) 22

5–7 m.; st. 5–7; p. 1; lvs. small, the lower opposite; stem erect . . *Loosestrife.* (Lythrum alatum) 31

large, lvs. pitcher-like . . . . . *Pitcher Plant.* (Sarracenia purpurea) 21

Fls. *blue* or *bluish*,

large, 3 m.; st. 3; p. 1;

lvs. sword-form, 1 in. wide . . . . *Blue Flag.* (Iris versicolor) 9

lvs. narrow, ¼–½ in. wide . . . . *Blue Flag.* (L. prismatica) 9

medium, 4 m.; st. 4; sympetalous; lvs. opposite.

petals fringed,

lvs. broad, short . . . . . *Fringed Gentian.* (Gentiana crinita) 35

lvs. narrow, short . . . . . (G. serrata) 35

petals closed, plaited . . . . . *Closed Gentian.* (G. andrewsii) 35

medium, irreg., 5 m.; sympetalous; st. 5; lvs. 2–6 in. long; sap milky; fls. many . . . . . *Blue Lobelia.* (L. syphilitica) 41

C.

HERBS.

Fls. *white*,

3 m.; lvs. =; st. 6;

fls. large, solitary nodding; lvs. 2, from bulb, spotted . . . . . *Dogtooth "Violet."* (Erythronium albidum) 5

Fls. small; in clusters; lvs. many, on a stem that comes from a rhizome . . . . . *False Solomon's Seal.* (Smilacina species ?) 6

3 m.; lvs. netted veined, 3 in number on a stem, broad; sepals green . . . . . *Trillium species ?* 6

4 m.; irreg., st. 6; p. 1; lvs. finely divided; "stemless."

Fls. breeches form; lvs. from clustered tubers . . . . . *Dutchman's Breeches.* (Bicuculla cucullaria) 19

Fls. heart form; lvs. from scattered tubers . . . . . *Squirrel Corn.* (B. Canadensis) 19

5 m.

Without petals; sepals petal-like; st. many; p. many;

fl. stalk from 3 lvs.;

fls. large; p. not woolly, but pubescent . . . . . *Anemone.* (A. Canadensis) 16

fls. small, pink tinged . . . . *Wind Flower.* (A. quinquefolia) 16

lvs. many; rad., 3 lobed;

lobes blunt; fls. also blue and pink . . . . . *Hepatica.* (H. hepatica) 16

lobes acute . . . . . (H. acuta)

With separate petals,

petals fringed; st. 10; lvs. in fours; nodes enlarged . . . . . *Starry Campion.* (Silene stellata) 14

st. many; p. many; lvs. 3-foliate, "stemless," with runners . . . *Strawberry.* (Fragaria species ?) 22

st. many; p. many; fls. crowded; lvs. pi. 7–11 foliate; tall . . . *Tall Cinquefoil.* 22
(Potentilla arguta)

st. many; p. many; lvs. 3 foliate, finely pubescent . . . . . *White Geum.* 22
(Geum Canadense)

With united petals,

stamens 10; p. 1; "stemless"; fls. several; lvs. thin, dull, elliptical, *Shin Leaf.* 33
(Pryola elliptica)

lvs. thick, shining, small . . . . (P. rotundifolia)

stamens 5; petals reflexed; fls. nodding, many on naked scape; lvs. rad., smooth . . . . . *Shooting Star.* 34
(Dodecatheon Meadii)

stamens 5; corolla funnel form; climbing vine; fls. large, morning-glory-like . . . . . *Bindweed.* 36
(Convolvulus species ?)

6–9 m.; st. 6–11; p. 1; sepals soon falling off; fls. large, between peltate lvs. . . . . *May Apple.* 17
(Podophyllum peltatum)

8–12 m.; sepals 2, soon falling off; st. many; p. 1; rhizome, with blood-red juice; lvs. rad. . . . *Bloodroot.* 19
(Sanguinaria Canadensis)

Fls. *yellow*,

3 m.; lvs. = ; st. 6; p. 1,

fls. large, solitary nodding; lvs. 2, from a bulb, spotted . . . . *Dogtooth "Violet."* 5
(Erythronium Americanum)

Fls. small, erect, 1–3; lvs. grass-like, from a solid bulb . . . . . *Star Grass.* 8
(Hypoxis hirsuta)

4 m.; st. 8; p. 1; stigma 4;

fls. large, nocturnal; stem leafy; petals rounded . . . . . *Evening Primrose.* 32
(Onagra biennis)

Fls. large, diurnal; stem leafy . . *Sundrops.* 32
(Kneiffia fruticosa)

5 m.; regular,

st. many; p. many, all on receptacle; lvs. much divided, small,

with narrow lobes, rad., from fleshy roots	*Buttercup.* (Ranunculus fascicularis)	
st. 10; p. 5; lvs. 3 foliate, rad. sour to taste; erect	*Sorrel.* (Oxalis stricta)	28
st. many; p. many; lvs. pa. 5 foliate,	*Fivefinger.* (Potentilla Canadensis)	22
5 m. irregular, spurred; st. 5; p. 1; lvs. heart-shape, on stem . . .	*Yellow Violet.* (V. Scabriuscula)	29
Fls. *red,*		
3 m.; st. 6; lvs. =;		
lvs. 3, on the stem, sepals green . .	*Red Trillium.* (Trillium recurvatum)	6
lvs. many, on stem; fls. large, lily-like, erect	*Meadow Lily.* (Lilium philadelphicum)	5
nodding, parts much recurved . .	*Turk's-cap Lily.* (L. superbum)	5
3 m.; st. 12; lvs. 2, kidney form; fls. in axil	*Wild Ginger.* (Asarum Canadense)	11
3 m.		
Fls. small,		
stamens 5; p. 1; sepals 2; lvs. narrow, from deep solid bulb; fls. striped with pink	*Spring Beauty.* (Claytonia Virginica)	13
stamens 10; lvs. 3-foliate from scaly bulb; sour leaves. . . .	*Wood Sorrel.* (Oxalis violacea)	28
Fls. medium,		
stamens 10; petals 2-lobed; lvs. opposite, entire, from enlarged nodes	*Fire Pink.* (Silene Virginica)	14
stamens 10; petals entire; lvs. opposite, or rad. palmate	*Crane's-bill.* (Geranium maculatum)	28
Fls. large,		
petals each spurred; st. many; p. 5; lvs. compound; fls. nodding .	*Columbine.* (Aquilegia Canadensis)	16

Fls. medium, clustered, sympetalous; lvs. opposite, narrow; st. 5, on petals; p. 1; plant pubescent . . . . *Sweet William.* (Phlox pilosa) 37

Fls. *blue*,

3-merous; sepals green; st. 6; lvs.; juice sticky; fls. ephemeral . . *Spiderwort.* (Tradescantia Virginica) 3

5 m. regular, sympetalous; st. 5, on petals;

lvs. opposite; fls. clustered; p. 1 . *Wood Phlox.* (Phlox divaricata) 37

irregular, polypetalous, spurred; st. 5; p. 1;

lvs. rad.;

heart-shaped . . . . . *Common Violet.* (Viola obliqua) 29

arrow-shaped . . . . . (V. sagittata)

finely divided; fls. large, pale . *Bird's-foot Violet.* (V. pedata) 29

Fls. *green*,

3-merous; st. 6; p. 1, on different plant from st.; lvs. broad; fls. carrion-scented;

with tendrils, tall . . . . . *Smilax.* (S. herbacea) 7

usually without tendrils, low . . (S. ecirrhata)

Shrubs or Bushes.

Fls. *white*,

4-merous; petals none; st. many; p. many; climbing . . . . . *Virgin's-bower.* (Clematis virginiana) 16

5-merous; petals separate; st. many, on sepals; p. many; stem with stout curved prickles; lvs. 3 foliate . . . . . *Blackberry.* (Rubus villosus) 22

petals united; st. 5; p. 1; lvs. pi. 5–11 foliate; fls. clustered, small; stem with much pith . *Elder.* (Sambucus Canadensis) 40

Fls. *yellow*,
lvs. opposite simple;
twining high; fls. 5 m.;
lvs. smooth, pale . . . . . *Yellow Honeysuckle.* 40
(Lonicera Sullivantii)
lvs. hairy, green . . . . . (L. involucrata)
erect, low, fls. 5 m. . . . . *Bush Honeysuckle.* 40
(Diervilla trifida?)

Fls. *red*,
large; st. many; p. many; lvs. pi. 5–9 foliate; stems prickly . . . . *Wild Roses.* 22
(Rosa species?)

TREES.

Fls. *white*,
trees small, thorny; fls. 5 m.; st. many; p. 1; style 1 . . . . . *Wild Plum.* 24
(Prunus Virginiana)
styles 3–5 . . . . . *Hawthorns.* 23
(Crataegus species?)
trees, small, thornless; petals 5; st. many; p. 1; lvs. simple, alternate; fls. in racemes . . . . *Choke Cherry.* 24
(Prunus Virginiana)
fls. in umbels . . . . . *Red Cherry.* 24
(P. Pennsylvanica)
trees large, thornless; petals 5; st. many; p. 1; lvs. simple, alternate; fls. small, in racemes . . *Black Cherry.* 24
(P. serotina)
trees large, thorny; fls. like pea flowers; lvs. pi. 9–19 foliate . . . *Locust.* 25
(Robinia pseud-acacia)

Fls. *yellow*,
lvs. abruptly truncate, pinnately veined; fls. large; petals 6; st. many . . . . . *Tulip Tree.* 15a
(Liriodendron tulipifera)
lvs. ovate, 3 lobed, pinnately-veined; fls. small, clustered, aromatic; st. 9; sep. 6 . . . . . *Sassafras.* 18
(S. sassafras)
lvs. 5 lobed, palmately veined; fls. small, clustered; 5 m.; st. 3–12; fruit-winged . . . . . *Hard Maple.* 27
(Acer saccharum)

Fls. *red* or *reddish*,

tree small, thorny; fls. large, odorous; 5 m.; st. many; p. 1; lvs. alternate . . . . . *Crab Apple.* (Malus coronaria) 23

tree small, thornless; fls. small; 4 m.; st. 4; lvs. opposite . . . . . *Wahoo.* (Euonymus atropurpureus) 26

D.

Fls. *white*,

large; petals none; st. many; p. many; lvs. finely divided, silky. *Pasque-flower.* (Anemone hirsutissima) 16

shrub, erect; st. many; p. 1; lvs. alternate, simple; fls. in umbels; 5 m., *Sand Cherry* (Prunus pumila) 24

Fls. *yellow*,

stem fleshy, leafless, spiny, jointed; fls. large; petals and stamens many, *Prickly Pear.* (Opuntia Rafinesquii) 30

stem ordinary, leafy; fls. small, clustered; 5 m., sympetalous; st. 5 on petals; fls. coiled in bud . . *Puccoon.* (Lithospermum species?) 38

Fls. *blue*,

sympetalous, reg.; 5 m.; st. 5; fls. bell-form, nodding or erect; lvs. on stem, narrow; juice milky . *Bluebell.* (Campanula rotundifolia) 41

MONOCOTYLEDONS.

Plants with one cotyledon, no distinction of pith, wood, and bark, leaves usually parallel veined, and flowers 3-merous.

1. *Pondweed Family.*

   Aquatic herbs with inconspicuous, greenish flowers, generally in spikes, with or without perianths; leaves often of two kinds, — submersed and floating, — the two kinds differing in form.

2. *Water Plantain Family.*

   Aquatic herbs, with leaves often netted veined; flowers commonly white, with many stamens and with few or many pistils, usually on separate flowers.

3. *Spiderwort Family.*
   Herbs with narrow leaves; generally blue flowers that are ephemeral; sepals usually green; stamens 3 or 6; pistil usually of 3 carpels; juice often mucilaginous.
4. *Pickerel Weed Family.*
   Aquatic herbs with irregular 6-merous flowers; stamens 6; pistil 1.
5. *Lily Family.*
   Herbs, often from bulbs; the regular flowers generally solitary or few, with the perianth of 6 divisions; stamens 6; pistil 1; the ovulary not attached to perianth, becoming a pod with few seeds.
6. *Lily of the Valley Family.*
   Similar to 5, but the flowers small, clustered, and stems from rhizomes.
7. *Smilax Family.*
   Similar to 5, but usually climbing vines, and with often imperfect greenish flowers in umbels; leaves broad and short petioled.
8. *Amaryllis Family.*
   Similar to 5, but with the ovulary attached to perianth tube.
9. *Iris Family.*
   Herbs, with colored perianth of two divisions, unlike in position and form of parts; stamens 3; pistil 1; with ovulary adherent to perianth tube and of 3 cells; leaves 2-ranked.
10. *Orchid Family.*
    Herbs, with irregular flowers, a petal modified as a "lip," 1 or 2 stamens adhering to the single pistil, and ovulary attached to the perianth tube and containing many small seeds.

DICOTYLEDONS.

Plants with 2 cotyledons, distinction of pith, wood, and bark or epidermis; usually netted veined leaves and 4–5-merous flowers.

A. APETALOUS (without petals).

11. *Birthwort Family.*
    Low herbs or climbing vines, with peculiar 3-merous axillary flowers; stamens a multiple of 3; leaves broad, netted veined.

12. *Buckwheat.*
    Herbs with alternate leaves; stems with swollen joints that are usually sheathed above by stipules; flowers 3–6-merous, generally racemed.

B. POLYPETALOUS (with separate petals).

13. *Portulacca Family.*
    Herbs, usually succulent, with 2 sepals and 5 petals; pistil 1; ovulary 1-celled, producing a many-seeded pod.
14. *Pink Family.*
    Herbs with simple opposite leaves from swollen joints; flowers 5-merous; stamens usually 10; ovulary 1-celled, but of several carpels, and with many seeds on a central placenta.
15. *Water Lily Family.*
    Aquatic herbs, usually with large leaves and flowers; 4–6 sepals, often with many petals and stamens.
16. *Crowfoot Family.*
    Herbs mostly; flowers 4–5-merous; stamens many; pistils few or many, distinct, generally becoming dry, akenes; all the parts separate on the receptacle.
17. *Barberry Family.*
    Plants with perfect, regular flowers: anthers opening by valves and a single simple pistil, which in fruit becomes a berry.
18. *Laurel Family.*
    Aromatic shrubs or trees, with commonly clustered flowers.
19. *Poppy Family.*
    Herbs with a milky or colored juice; regular or irregular flowers; pistil 1-celled with 2 or more parietal placentæ.
20. *Mustard Family.*
    Herbs with pungent juice; alternate leaves; 4-merous flowers with 6 stamens of 2 sorts, and 1 pistil of 2 carpels, becoming a pod in fruit.
21. *Pitcher Plant Family.*
    Herbs with leaves modified into receptacles to hold water and catch insects.
22. *Rose Family.*
    Herbs, shrubs, or trees with alternate stipulate leaves, 5-merous flowers; stamens many on the calyx; pistils many, becoming akenes.

23. *Apple Family.*
Similar to 22, but pistil 1 only, of several carpels, becoming a pome.

24. *Plum Family.*
Similar to 22, but with a single pistil, becoming a drupe.

25. *Pea Family.*
Herbs, shrubs, or trees with irregular 5-merous flowers; stamens 10, in 2 sets of 9 and 1; a single simple pistil, becoming a pod; leaves usually compound.

26. *Staff Tree Family.*
Shrubs or trees, with 4–5-merous flowers; stamens 4–5, often inserted on a disk; pistil 1, with 2–5 cells.

27. *Maple Family.*
Trees, with palmately veined, simple opposite leaves (or sometimes with compound leaves) and clustered, usually inconspicuous flowers.

28. *Geranium Family.*
Herbs, with regular 5-merous flowers; stamens 10; pistil single; and ovulary several-celled.

29. *Violet Family.*
Herbs, often apparently "stemless," with irregular 5-merous flowers, which are spurred; stamens 5; pistil 1; one-celled with 3 parietal placentæ, becoming in fruit a pod.

30. *Cactus Family.*
Herbs, generally with swollen, distorted, jointed, prickly stems, no foliage leaves, and often with large flowers of many petals and stamens; fruit a berry.

31. *Loosestrife Family.*
Herbs, with perfect 4–7-merous flowers, with ovulary and pod inclosed in the calyx tube, but free from it.

32. *Evening Primrose Family.*
Herbs, with alternate simple leaves; 2–4-merous flowers; stamens usually 8; a single 4-celled pistil adherent to the calyx, in fruit becoming a pod.

C. SYMPETALOUS (with united petals).

33. *Wintergreen Family.*
Mostly shrubs, with regular 4–5-merous flowers; anthers 2-celled, usually opening by a hole at the end; pistil 1, usually of the same number of cells as the petals.

34. *Primrose Family.*
Herbs, with 5-merous flowers; stamens 5, opposite to the petals; pistil 1, with 1 cell and a free central placenta.

35. *Gentian Family.*
Herbs, with bitter juice, opposite leaves, and 4-merous regular flowers; stamens 4; pistil 1; with a 1-celled ovulary with 2 parietal placentæ.

36. *Morning Glory Family.*
Herbs, often climbing, with alternate leaves, regular 5-merous flowers; 5 stamens, and a single pistil, becoming a 2 to 4-celled pod.

37. *Phlox Family.*
Herbs, with usually opposite leaves; 5-merous flowers, regular and commonly salver form; 5 stamens and 1 pistil, with 1-celled ovulary and 1 parietal placenta.

38. *Borrage Family.*
Mostly herbs with rough foliage, alternate leaves; 5-merous regular flowers in a coiled inflorescence; 5 stamens and 1 pistil with a 4-parted ovulary.

39. *Bladderwort Family.*
Aquatic herbs, leaves often with bladder-like attachments; flowers irregular.

40. *Honeysuckle Family.*
Mostly shrubs, often climbing, with opposite leaves; 5-merous, often irregular flowers, which are commonly tubular; stamens generally 5; pistil 1.

41. *Bell Flower Family.*
Herbs, with milky juice, alternate leaves and regular or irregular 5-merous flowers; stamens 5; pistil 1; ovulary 2 to 5-celled and adherent to calyx.

42. *Composite Family.* (Not represented in key.)
Dandelion, aster, sunflower; herbs mostly in temperate regions, with 5-merous flowers, crowded in a head and surrounded by a common involucre.